NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

THESIS

THE THREAT OF RADIOLOGICAL TERRORISM

by

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September 1996

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2.REPORT DATE September 1996	3.REPORT TYPE AND DATES COVERED Master's Thesis

4.TITLE AND SUBTITLE The Threat of Radiological Terrorism	5.FUNDING NUMBERS
6.AUTHOR(S) Matthew E. Woods	
7.PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey CA 93943-5000	8.PERFORMING ORGANIZATION REPORT NUMBER
9.SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11.SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a.DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13.ABSTRACT *(maximum 200 words)*

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14. SUBJECT TERMS Radiological Weapons, Terrorism, Weapons of Mass Destruction, Intelligence	15.NUMBER OF PAGES 126
	16.PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19.SECURITY CLASSIFICATION OF ABSTRACT	20.LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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THE THREAT OF RADIOLOGICAL TERRORISM

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF ARTS IN NATIONAL SECURITY AFFAIRS

from the

NAVAL POSTGRADUATE SCHOOL
September 1996

ABSTRACT

WMD terrorism is a new concern. The United States is preparing for the possibility of terrorist acts involving chemical, biological, and nuclear weapons, but the scope of these preparations is too narrow. This thesis argues that radiological devices are also viable weapons of mass destruction for terrorism. Radiological weapons are not nuclear explosives; they are designed to disperse radioactive material over an area by mechanical means or conventional explosives. The potential for radiological terrorism depends upon access to the required nuclear materials and the motivations for terrorists to use radiological weapons. Radiological weapons can use non-weapons grade nuclear material which is widely accessible throughout the world. The material is under a spectrum of physical security systems with little accountability and verification. Radiological weapons can further terrorist objectives because they can be used to contaminate individuals without producing the immediate and widespread catastrophic damage normally associated with WMD. This prospect of contamination is enough to incite the public's fear of the nuclear unknown or nuclear phobia. To counter radiological terrorism, the U.S. government should expand indications and warning through efforts to maximize the intelligence community's human intelligence assets and exploit open source collection.

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LIST OF ACRONYMS

CIA	U.S. Central Intelligence Agency
CIS	Commonwealth of Independent States
DCI	Director of Central Intelligence
DOE	U.S. Department of Energy
FSU	Former Soviet Union
HLW	High Level Waste
HUMINT	Human Intelligence
IAEA	International Atomic Energy Agency
LLW	Low Level Waste
NATO	North Atlantic Treaty Organization
NOC	Non-official Cover Agent
NPC	DCI Nonproliferation Center
NRC	U.S. Nuclear Regulatory Commission
OSINT	Open Source Intelligence
TUR	Transuranic Waste
WMD	Weapons of Mass Destruction

EXECUTIVE SUMMARY

The March 1995 Aum Shinrikyo sarin gas attack in Japan set the precedent for the successful use of weapons of mass destruction (WMD) by a sub-state actor. The placing of cesium-137 by Chechen separatists in Izmailovsky Park, Moscow on 23 November 1995 was the first widely publicized act of radiological terrorism. Future cases of WMD terrorism can not be discounted.

The United States is preparing for the possibility of terrorist acts involving chemical, biological, and nuclear weapons. However, focusing solely on those weapons as the primary weapons for WMD terrorism is too narrow. This thesis argues that radiological devices are viable weapons of mass destruction for terrorism. The potential for radiological terrorism depends upon access to the required nuclear materials and the motivations for terrorists to use radiological weapons.

Radiological weapons can use non-weapons grade nuclear material which is widely accessible throughout the world. Numerous industries use a wide range of radionuclides in their day to day operations. These radionuclides are under a spectrum of physical security systems with little or no transparency for accountability and verification. Inadequate security and lack of transparency in radionuclide industries create a path of least resistance whereby nuclear material can be obtained by theft or diversion. Furthermore, all of the required technical knowledge for acquisition and production of radiological weapons is available through open sources.

The utility of radiological weapons is based on the technical aspects of radionuclides and the psychological aspects of nuclear phobia. Radiological weapons can contaminate individuals with either a dose equal to or greater than the annual permissible dose allowed by U.S. law without producing the immediate and widespread catastrophic damage normally associated with WMD. This contamination is enough for terrorists to tap into the public's fear of the unknown and to trigger the nuclear fear that is well established in many societies throughout the world. Nuclear fear and the general risk of cancer give credibility to the psychological aspect of radiological weapons.

Radiological weapons can be superb psychological terror weapons. The weapons allow terrorist organizations to operate on the threshold that separates acts of violence from being ineffective in attaining their goals and from being overly devastating so that internal and external support for their cause is lost. The radiological terrorism threat can be diminished by undermining the psychological aspects of radiological weapons. Once the fear is gone, risk perception will decrease, and the foundations of nuclear phobia will crumble.

Present U.S. resources can be best employed against radiological terrorism by expanding indications and warning, maximizing the intelligence community's human intelligence assets, and accessing and exploiting open source collection. The DCI's Nonproliferation Center can show policy makers that radiological weapons can not be dismissed. The inability to prepare for new threats may leave the United States vulnerable to those threats.

I. INTRODUCTION

The RAND Chronology of International Terrorism has recorded fifty-two attempted terrorist attacks using weapons of mass destruction (WMD) since 1968.[1] The fifty-two incidents range from "plotting such attacks, attempting to use chemical or biological agents or to steal, or otherwise fabricate on their own nuclear devices."[2] These previous attempts at WMD terrorism illustrate the fact that some terrorist organizations are willing to escalate to WMD in order to draw more attention to their cause.

Two recent events exemplify the world's vulnerability to WMD terrorism: the March 1995 sarin gas attack in the Tokyo subway and the box of cesium-137 found on 23 November 1995 in Izmailovsky Park, Moscow. The Aum Shinrikyo gas attack in Japan set the precedent for the successful use of WMD by sub-state actors. The placing of cesium-137 by Chechen separatists in Izmailovsky Park was the first widely publicized act of radiological terrorism.

Terrorist acts have become increasingly more violent over the past few decades.[3] As terrorists turn to increasingly more lethal methods to gain notoriety, radiological weapons may be the terrorist's next choice. Radiological weapons are the niche between conventional explosives and true WMD.

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[1] Bruce Hoffman, Terrorist Targeting: Tactics, Trends, and Potentialities, P-7801 (Santa Monica: RAND, 1992), 3.

[2] Bruce Hoffman, Responding to Terrorism Across the Technological Spectrum (Carlisle Barracks: Strategic Studies Institute, U.S. Army War College, 15 July 1994), 3.

[3] Hoffman, Terrorist Targeting, 3-10.

A. DEFINITION OF RADIOLOGICAL WEAPONS

Radiological weapons are devices designed to disperse radioactive material over an area by mechanical means or conventional explosives.[4] Radiological terrorism includes sabotage attacks against nuclear power reactors and attacks against nuclear waste storage tanks. Attacks against nuclear facilities would be an attempt to produce contamination on the scale of the Chernobyl accident.

Radiological weapons are considered WMD because they contain nuclear material. These weapons produce neither the blast effects or the extreme temperatures associated with nuclear weapons, nor the immediate catastrophic deaths normally associated with chemical and biological weapons. The intended results of a radiological weapon can be any combination of the following: psychological, public panic, disruption, radioactive contamination, or hazardous health conditions.

B. NATURE OF THE PROBLEM

Terrorist organizations need the media to spread their propaganda and reach their target audience. Acts of violence are required to gain media coverage. Over the past few decades developing trends indicate that conventional acts of terrorism are increasingly more violent. The next step from conventional methods may be WMD.

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[4] The terms radiological weapon and radiation dispersal device have been used interchangeably since the early 1970's. This thesis refers to all devices using radioactive nuclear material, with the exception of strategic and tactical nuclear weapons, as radiological weapons.

The March 1995 Aum Shinrikyo sarin gas attacks confirms that conventional terrorism has crossed the threshold to WMD terrorism. This is not to say that every act of terrorism will be WMD terrorism. The majority of terrorists acts will continue to be carried out with conventional methods until these tactics become routine; whereby the next step in innovation may lead to WMD. The highly publicized acts of Aum Shinrikyo and the Chechen separatists have spread the idea of WMD terrorism throughout the world. Terrorist organizations desiring to use WMD will study past acts of WMD terrorism and improve future dispersal scenarios.

The United States is committed to deterring and countering WMD terrorism. Extensive research and analysis has been conducted by U.S. government agencies and non-government organizations. The WMD focus is on nuclear, chemical , and biological weapons. These weapons can cause immediate, wide spread death and destruction. This is a legitimate focus. As a nation-state we are concerned with protecting our society from threats. The greatest threats come from WMD. Therefore it is logical to put the greatest amount of U.S. resources and analysis on true WMD. This means that radiological weapons, which can not cause immediate, widespread death and destruction, have become low priority threats.

C. ARGUMENT

Current U.S. WMD policy is too narrow and underestimates radiological weapons. Radiological devices are viable weapons for WMD terrorism. If the U.S. intelligence community and policy makers fail to understand the implications of radiological weapons, then the United States may find itself vulnerable to radiological terrorism.

This thesis argues that radiological devices are viable weapons for WMD terrorism. Radiological weapons are only viable weapons if the nuclear material required to produce them is accessible and if terrorists are motivated to use the weapons. This thesis will show that the nuclear material is accessible throughout the world by theft or diversion. It will also discuss the motivations for using radiological weapons: psychological aspects, technical aspects, choice radionuclides for terrorism, and dispersal scenarios. Understanding the viability of radiological weapons and how they might be employed by terrorists allows U.S. organizations and the intelligence community to possibly deter the initial use of the weapons and prepare appropriate responses to minimize casualties and damage.

D. THESIS ORGANIZATION

This thesis is divided into five chapters. The first chapter introduces the argument and general issues. The second chapter discusses the psychological aspects of radiological weapons and the technical aspects of eight radionuclides that can be used for radiological weapons. The third chapter determines the availability of nuclear material throughout the world for radiological weapons. This is accomplished by examining the abundance of radionuclides in various fields: medicine, commercial industry, food industry, nuclear power, and nuclear weapons and the physical security of the nuclear material. The fourth chapter discusses the motivations for radiological terrorism and examines radiological dispersal scenarios. No U.S. government agency nor the intelligence community can effectively deter, counter, or minimize casualties and damage without an accurate depiction of the types of situations where radiological weapons might be employed. The concluding chapter discusses the major findings of the thesis and the implications of radiological terrorism for the U.S. intelligence community.

II. RADIOLOGICAL WEAPONS - A THREAT OF THE FUTURE

The U.S. WMD focus centers around the fact that the United States is primarily concerned with chemical, biological, and nuclear weapons. Yet, radiological devices possess both the psychological -- nuclear phobia and risk perception -- and technical aspects -- radioactive contamination -- to be sufficiently complementary to terrorism. Radiological weapons receive inadequate focus in the United States. The correct focus needs to distinguish radiological terrorism from nuclear terrorism.

This chapter discuses the psychological and technical aspects of radiological weapons. Nuclear phobia is supported by two case studies -- Three Mile Island and Chernobyl -- and the public's perception of risk. The technical section of the chapter examines eight radionuclides. The technical characteristics -- the radionuclide's half-life, particle emission, and the permissible limits by inhalation and oral intake -- support the fact that it requires a small amount of nuclear material to contaminate an individual. This contamination can trigger or reinforce nuclear phobia.

A. U. S. WMD FOCUS

The United States is committed to deterring and countering the use of WMD against its territories, its armed forces, and its allies. Deterrence, as a matter of policy, is primarily focused against other nation-states; nation-states are the greatest threat to the sovereignty of the United States and its vital interests. The secondary focus of deterrence is on sub-state actors; who can hold a society hostage through the threat of detonation or detonation of a nuclear, chemical, or biological weapon.

In an era of declining defense budgets, the present U.S. focus and resource allocation against WMD is logical. However, the scope of the focus is too narrow. It underestimates radiological weapons. Radiological devices have two distinct aspects: technical and psychological. U.S. government analysis relies on the technical merits of a radiological weapon. It must be understood that radiological weapons can not cause the immediate wide spread death and destruction associated with nuclear, chemical, or biological weapons. However, radiological weapons are excellent terror weapons and the United States is clearly susceptible to the psychological terror of these weapons.

B. NEW U.S. CONCERN: RADIOLOGICAL WEAPONS

Radiological weapons may not be able to produce the massive deaths which can be produced by nuclear, chemical or biological weapons, but they can instill phenomenal fear and widespread panic within a society. Current policy and politics will never allow radiological weapons to be classified as anything other than WMD because the weapons contain nuclear material and they produce fear and paranoia similar to true WMD.

Even though radiological weapons are considered WMD, there is no international treaty prohibiting the production or use of radiological weapons.[5] The opportunity and propensity for terrorists to use radiological devices continues to exist today. Radiological weapons are an excellent choice for terrorists to use to hold a society hostage to their demands. The mere mention of nuclear material strikes fear into the public and plays on the nuclear phobia which exists throughout the world.

Clearly, a definition of radiological terrorism is required. As such, it is useful to distinguish between nuclear terrorism and radiological terrorism. There is a greater threat from radiological terrorism than there is from a terrorist organization obtaining and detonating a nuclear weapon.

1. Nuclear Terrorism

Since the early 1970's, nuclear terrorism has been defined as all acts of terrorism involving weapons containing nuclear material.[6] Karl-Heinz Kamp states that nuclear terrorism ranges

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[5] Ambassador Thomas Graham Jr., Special Representative of the President for Arms Control and Non-proliferation and Head of the United States Arms Control and Disarmament Agency, lecture given at the Naval Postgraduate School on 30 November 1995. Ambassador Graham stated that a treaty banning radiological weapons was considered in Geneva until 1984. The primary focus was on terrorist attacks against commercial nuclear power plants. The treaty never materialized because of the lack of consensus concerning the dangers of radiological weapons.

[6] A comprehensive and historical overview of nuclear terrorism can be found in the following citations: Louis Rene Beres, Terrorism and Global Security: The Nuclear Threat (Boulder: Westview Press, 1979); Paul Leventhal and Yonah Alexander, eds., Nuclear Terrorism: Defining the Threat (Washington: Pergamon-Brassey's International Defense Publishers Inc., 1986); Paul Leventhal and Yonah Alexander, eds., Preventing Nuclear Terrorism: The Report and Papers of the International Task Force on Prevention of Nuclear Terrorism (Lexington: Lexington Books, 1987); Frank Barnaby, Weapons of Mass Destruction: A Growing Threat in the 1990's?, Conflict Studies 235 (London: Research Institute for the Study of Conflict and Terrorism, October/November 1990), 3-15; Karl-Heinz Kamp, Nuclear Terrorism - Facts and Fiction (Sankt Augustin near Bonn: Konard-Adenauer-Stiftung, Department of Political Research, 1995);

from the actual detonation of nuclear weapons or acts of nuclear violence, for example, in the form of the release of radioactive substances or the radioactive contamination of drinking water, to acts of sabotage in and against nuclear power plants. The 'nuclear' aspect can either relate to the means employed by the terrorists (nuclear weapons) or to their target (i.e., nuclear reactors).[7]

This definition is too broad. In many countries throughout the world, especially in the United States, there is a fear of anything nuclear. Kamp's broad definition of nuclear terrorism can be used to spread fear which can result in public panic. The horrific image of the mushroom cloud and the resulting massive destruction are associated with the term "nuclear terrorism." Yet Kamp's definition includes much more than nuclear weapons. A more realistic definition is required for U.S. policy.

2. Radiological Terrorism

The first step in defeating the nuclear fear and increasing public awareness is to redefine the threat in realistic terms. The term nuclear terrorism should refer only to terrorism conducted with a nuclear weapon, while radiological terrorism should refer to all other incidents using nuclear material. Therefore, the definition of radiological terrorism is terrorism designed to coerce a government to change one of its policies by inducing or attempting to induce widespread public panic through the detonation or threat of detonation of a radiological device. Supporting objectives might include monetary or

and Uwe Nerlich, The Political and Strategic Analysis of Nuclear Non-state Actors and Sponsoring States: What to Look For? (Ebenhausen, Germany: Stiftung Wissenschaft und Politik (SWP), Forschungsinstitut fur Internationale Politik und Sicherheit, August 1994), Report Prepared for Sandia National Laboratories.

[7] Karl-Heinz Kamp, Nuclear Terrorism - Facts and Fiction, 3-4.

economic extortion, inflicting an unacceptable level of casualties, degrading foreign military capabilities by disrupting force mobilization, command and control, and intelligence activities, dissolving an international coalition;[8] or "to compensate for NATO's superiority in conventional forces and technology."[9]

Redefining the definitions is key to constructing a viable national policy to counter the use of radiological weapons and to be able to discuss possible scenarios in realistic terms. One must remember that it may be possible for a terrorist organization to obtain and use a nuclear weapon, but it is highly improbable that it will occur. Nuclear weapons in the five declared nuclear weapon states are under tight control and security. [10] A terrorist organization will need sponsorship of a nation-state to safely obtain, transport, and use a nuclear weapon. In this unlikely event, the sponsoring non-nuclear weapon state will maintain control of the stolen nuclear weapon because it would be their "trump card" in any regional conflict or superpower intervention against that nation-state.

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[8] Robert Grant, Counterproliferation and International Security: The Report of a U.S.-French Working Group (Arlington: U.S.-Crest, 1995), 11.

[9] Gregory L. Schulte, "Responding to Proliferation - NATO's Role," NATO Review, July 1995, 18.

[10] The five nuclear weapon states are the United States, Russia, China, Great Britain, and France.

C. PSYCHOLOGICAL ASPECTS OF RADIOLOGICAL WEAPONS

1. Nuclear Phobia

Nuclear phobia is defined as the real and perceived fear associated with the atom. The real fear is based on the effects of ionizing radiation and the destructive power of nuclear weapons. The perceived fear is based on the misconceptions, fear of the unknown, and lack of public awareness concerning nuclear energy which are common in today's society.

Nuclear phobia was solidified by the dropping of the atomic bombs on Hiroshima and Nagasaki. The phobia has been grown and cultivated over the past forty years. "A word association study in the 1970's illustrated that of emotional responses to the word 'atom,' the majority of people thought of 'Hiroshima,' 'death,' and 'destruction.'[11] Clearly, these perceptions continue to plague the atom."[12]

The power of the atom was not only harnessed for its destructive power, but also as an almost limitless source of energy. Beginning with the U.S. Atoms for Peace program, the advanced nuclear states spread commercial nuclear power around the globe. As it spread so did the accompanying nuclear phobia. Despite the widespread fear of the atom, many scientists continue to hail nuclear power as the energy solution for the twenty-first century. However, this view is not shared by society. The general public

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[11] Spencer Weart, Nuclear Fear: A History of Images (Cambridge: Harvard University Press, 1988), 5.

[12] David Williams, "Why Countries Want Nuclear Weapons: Postmodernism and Nuclear Proliferation," Unpublished Research Paper (Monterey: Naval Postgraduate School, July 1996), 14.

knows very little concerning the advantages and disadvantages of nuclear power.[13] The public still fears the atom because of its destructive power.

Nuclear phobia is reinforced by accidents in the nuclear power industry. The two most significant accidents are Three Mile Island and Chernobyl. Both are examined for their real radiological concerns and their contributions to enhancing the nuclear phobia that exists today.

a. Three Mile Island Case Study

The Three Mile Island accident occurred 28 March 1979, approximately ten miles south of Harrisburg, Pennsylvania. The accident was due to the loss of coolant to the reactor core, which caused a partial melt down. Despite the common perception, there was no catastrophic nuclear accident at this plant. There were small, isolated releases of radioactive material -- venting of safety valves to relieve pressure -- into the atmosphere for three days. The releases did not cause any health effects to the surrounding population in Pennsylvania or neighboring states.[14] Sixty plant employees

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[13] A brief summary of the advantages of nuclear power industry can be found in the following documents: Nuclear Regulatory Commission Information Digest 1995 Edition, NUREG-1350 Vol. 7 (Washington: U.S. Nuclear Regulatory Commission, Office of Administration, Printing and Mail Services Section, 1995); NRC: Regulator of Nuclear Safety, NUREG/BR-0164, Rev. 1 (Washington: Office of Public Affairs, June 1993); Nuclear Energy Facts: Questions and Answers (Chicago: American Nuclear Society, 1988); Nuclear Energy Low-Level Radioactive Wastes (Chicago: American Nuclear Society Public Communications Department, 1993); and Transporting Radioactive Materials (Chicago: American Nuclear Society Public Communications Department, 1993).

[14] A complete explanation and summary of the nuclear power accident at Three Mile Island can be found in the following sources: Report of the President's Commission on the Accident at Three Mile Island, The Need For Change: The Legacy of TMI (Washington: Government Printing Office, 1979); Mark Stephens, Three Mile Island (New York: Random House, 1980); and "Nuclear Power Accident," Facts on File World News Digest, 6 April 1979, 241, A1.

were contaminated during the accident; none of whom required hospitalization. All releases of radioactive material or exposure were within the Nuclear Regulatory Commission's legal limits.

Three Mile Island had a profound psychological impact upon the general public in the United States and to a smaller extent, elsewhere. The public's nuclear phobia and their fear of the unknown were increased by the declared state of emergency, the media's coverage of the accident, and by the statements made by public officials concerning the possible effects of a catastrophic failure at a nuclear power plant. The hysteria began with the initial media coverage of the accident.

The first reports dealt with the releases of the radioactive gases -- iodine, krypton, and xenon -- over a four county area. These reports were followed by the detection of low levels of radiation in the atmosphere as far as twenty miles from Three Mile Island. The media reported the fact that the reactor building had over one thousand times the normal level of radiation; which is a logical consequence to the flooding of the room enclosing the reactor. The fact that the contamination was contained in the reactor building was down-played in the media. There was even an inaccurate report of a single sample of iodine contaminated milk found five miles from Three Mile Island. This milk contamination claim was dismissed due to the fact that the traces of iodine were close to the minimum measurable level.[15]

[15] "Nuclear Power Accident," A1.

The most significant contributions to the public's nuclear phobia came from public officials and university professors. Governor Thornburgh advised pregnant women and preschool children within a five mile radius of Three Mile Island to leave the area until further notice. He ordered twenty-three schools closed and advised the surrounding population to stay indoors until the end of the state of emergency. Nuclear phobia continued to grow as the media broadcast negative comments concerning the accident and the release of radiation. George Wald, Nobel Prize winning biologist, stated that "every dose of radiation is an overdose. A little radiation does a little harm and more of it does more harm."[16] Ernest Sternglass, University of Pittsburgh radiology professor, stated that "the reaction of the community should be to stand up and scream. The risk for pregnant women and young children is significantly increased."[17]

All of the aforementioned actions and statements were made for the safety of the public, but they bordered on being overly cautious and contributed to the town's over-reaction. People made "extraordinary withdrawals" from banks in the surrounding areas;[18] approximately twelve hundred people moved to civil defense emergency shelters; and five percent of the twenty thousand people within a mile radius of Three Mile Island left the area. The perceived danger combined with nuclear phobia and fear of the unknown drove people to overreact. It can be seen how easy it would be for a terrorist to play upon the nuclear phobia of these people.

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[16] "Nuclear Power Accident," A1.

[17] "Nuclear Power Accident," A1.

[18] "Nuclear Power Accident," A1.

b. Chernobyl Case Study

Chernobyl, the worst nuclear accident in history, occurred 26 April 1986.[19] It was the result of a loss of control over a test designed to stop the coolant flow to the reactor. The loss of control culminated in an explosion in the reactor building, which produced a massive release of radiation into the atmosphere and contaminated ground debris. Nuclear isotopes consisted of cesium-137, iodine, plutonium-239, strontium-90, and uranium. The Soviet Union estimated that half of the released radioactive material fell within an eighteen mile radius of Chernobyl.[20] The remaining material was spread over parts of Russia, Belarus, Ukraine, and Europe. Over seventeen and a half million people live in the most severely affected regions of Belarus, Ukraine, and Russia.

The Chernobyl disaster reinforced nuclear phobia for millions of people and increased the fears of long term health risks from radioactive fallout. These fears have not diminished despite the fact that the World Health Organization determined that there were no immediate acute health effects beyond the region surrounding the reactor and some "hot spots" in the Soviet Union and Europe, which were created by rain bearing

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[19] A comprehensive summary of the 1986 Chernobyl nuclear accident can be found in the following sources: Barbara Crossette, "Chernobyl Fund Depleted as Problems Rise," New York Times, 29 November 1995, A11; Piers Paul Read, Ablaze: The Story of the Heroes and Victims of Chernobyl (New York: Random House, 1993); Grigori Medvedev, No Breathing Room: The Aftermath of Chernobyl (New York: Basics Books, 1993); Grigori Medvedev, The Truth About Chernobyl: An Exciting Minute-By-Minute Account By a Leading Soviet Nuclear Physicist of the World's Largest Nuclear Disaster and Coverup (New York: Basic Books, 1991); V.M. Chernousenko, Chernobyl: Insight from the Inside (New York: Springer-Verlag, 1991); "Learning From Chernobyl," Foreign Affairs, 1986/1987 Winter, 304; and David R. Marples, Chernobyl & Nuclear Power in the USSR (New York: St. Martin's Press, Inc., 1986).

[20] "Learning From Chernobyl," 304.

radioactive clouds.[21] These are genuine fears since no extensive medical research has been done on long term health effects created by exposure to low levels of ionizing radiation.[22] The nuclear phobia produced by the Chernobyl disaster is a result of real radiological effects to the surrounding populations.

The radiological effects are composed of both physical and psychological factors. There are four physical aspects of the disaster. First, a total of thirty-one people died from Chernobyl; two of which were a direct result of the explosion. Second, two hundred nine people were hospitalized for thermal burns and acute radiation poisoning. Third, six hundred ninety-six thousand people were given medical exams. Over eighty percent of these people were immediately released. Finally, one hundred thirty-five thousand people were evacuated from a thirty kilometer radius from the Chernobyl nuclear power plant.[23] The massive number of people evacuated increased the fear of nuclear power. The mere mention of a radiological weapon or nuclear reactor sabotage that could produce effects on the scale of the Chernobyl disaster strikes fear in millions of people throughout the world.

The psychological impact is composed of three factors. First, the massive evacuation of the thirty kilometer zone was required not only for the safety of the people living in the region, but the size of the evacuation zone became the psychological standard

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[21] "Learning From Chernobyl," 304.

[22] The most extensive medical research on long term radiation effects has been done on the survivors of Hiroshima and Nagasaki. These effects were the direct result of exposure to high levels of radiation produced by atomic weapons.

[23] "Learning From Chernobyl," 304.

by which people immediately judge reports of nuclear accidents. Second, the European Economic Community banned all fresh food imported from countries within a one thousand kilometer radius of Chernobyl. The ban was a result of the perceived risk of an increasing cancer and thyroid maladies.[24] Third, Poland publicly announced that it was administering potassium iodine to its children to decrease the effects of exposure from the radioactive fallout.

Fears of increases in the risk of cancer or being contaminated by nuclear material drove Europe and neighboring countries to the aforementioned measures. Nuclear phobia and the concern for future generations, regardless of a real or perceived threat, overrides any desire for profit from trade. Countries turn isolationist in the event of a nuclear accident. This isolationism is a result of not only the nuclear phobia, but also the public's ignorance and lack of awareness concerning the atom.

The nuclear phobia that began ten years ago at Chernobyl was rekindled on 23 April 1996. A forest fire burned for seven and half hours in an eighteen mile exclusion zone surrounding Chernobyl. Strong winds blew contamination towards Kiev. The exclusion zone is one of the most heavily contaminated areas of cesium-137.[25] Radiation

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[24] "Learning From Chernobyl," 304.

[25] "Chernobyl Fire Releases Radioactivity," Monterey County Herald, 24 April 1996, A2.

levels inside the exclusion zone ranged from "four to ten-fold increase in the radiation from cesium in certain areas"[26] after the fire.[27]

The scare over new contamination was increased when Ukraine authorities announced on 25 April 1996 that a container of radioactive material was not completely sealed, nor was it properly disposed of by workers at the nuclear power plant.[28] The fears of new contamination and the carelessness by the workers at Chernobyl during the anniversary week of the Chernobyl disaster reinforces the world's nuclear phobia and perception of the risks involved in nuclear power.

c. Summary of Nuclear Phobia Case Studies

Although nuclear phobia was solidified with the dropping of the atomic bomb in 1945, it is as strong as ever today. Both Three Mile Island and Chernobyl reinforced the public's nuclear phobia. There are real concerns over a nuclear disaster. A disaster could be caused by a catastrophic failure of a nuclear plant's safety features or as a direct result of sabotage by terrorists. Nuclear phobia will continue to grow as long as the general public remains ignorant of the facts concerning the atom.

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[26] "Chernobyl Forest Fire Sparks Fears of Radiation," Monterey County Herald, 25 April 1996, A2.

[27] The significance of this observation can not be determined. It can be assumed that the increase is above the normal radiation level; yet one must ask how dangerous the increase is? Incomplete reporting and attempts to quantify dangers can increase the public's fear.

[28] "Radioactive Debris Found at Chernobyl," Monterey County Herald, 26 April 1996, A2.

2. Risk Perception and Nuclear Phobia

Terrorists can use the nuclear phobia that pervades the United States and the world to their advantage. Nuclear phobia is enhanced by the perception of significant health risks caused by the exposure to ionizing radiation, which increases the probability for cancer. The actual probabilities for increasing the risk of cancer are all scenario dependent. The length of exposure, dose, type of isotope, and method of exposure -- ingestion or inhalation -- are variables that must be accounted for in determining the risk of cancer. The risk is generally very low and insignificant when compared to the number of naturally occurring cases of cancer.

The scientific facts concerning the dangers of exposure to ionizing radiation are lost on the general public. Risk perception, evaluation, and regulatory efforts are driven by the "the public's fear of cancer."[29] Thus, government regulation is driven by the public's perception of any threat which can cause a major risk of increasing cancer.[30]

The general public's perception of risk is radically different from experts in the various scientific fields. Experts base their risk assessments upon scientific findings. The public bases its risk perception upon the negative attributes of hazards. The five attributes that have the greatest impact upon nuclear phobia are: (1) involuntary exposure to risk, (2) lack of personal control over the outcome, (3) uncertainty about the

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[29] Stephen G. Breyer, Breaking the Vicious Circle: Toward Effective Risk Regulation (Cambridge: Harvard University Press, 1993), 3.

[30] Breyer, Breaking the Vicious Circle, 3.

probabilities or consequences of exposure, (4) fear of the unknown, and (5) genetic effects of exposure which could threaten future generations.[31]

The lack of public awareness prevents a majority of the general public from accepting the views of the experts. This is particularly true with nuclear power. "Risks associated with toxic waste dumps and nuclear power appear near the bottom of most expert lists; they appear near the top of the public's list of concerns."[32] Nuclear phobia is based on the public's perception of the risks involved in uncontrollable and catastrophic nuclear threats to society and future generations.

There has been a growing distrust of experts, academics, and government institutions since the mid-1960s.[33] This is primarily due to the fact that the experts can not agree with each other, nor do they agree with government officials. The public does not know whom to consider an expert or which expert is actually correct.

The lack of confidence and trust in experts and the government creates an environment which allows nuclear phobia to thrive. Questions concerning a nuclear threat deal directly with the public's safety, health issues, risk of cancer, proper response, and environmental clean up. If there is no confidence in the information presented by the government concerning a radiological weapon, then the government may face extreme

[31] Risk: Analysis, Perception and Management, Report of a Royal Society Study Group (London: Royal Society, 1992), 101.

[32] Breyer, Breaking the Vicious Circle, 33.

[33] Breyer, Breaking the Vicious Circle, 36.

public pressure to appease the terrorists because of the horrific images of WMD. The lack of trust has a significant impact upon the responses to radiological terrorism.

3. Radiological Terrorism, the Media, and Risk Perception

Appeasement of terrorist demands means that the terrorist organization has obtained its objectives. A successful terrorist act will give credibility to the terrorist organization and give the organization power in the international political arena. Therefore, terrorists may choose a weapon that will obtain their goals while simultaneously giving them increased status in the international political arena. A radiological weapon fulfills the terrorist requirements.

Radiological terrorism relies upon nuclear phobia and risk perception. The sub-clinical effects of radiological weapons, which increase the public's fear of an increased risk of cancer, allow terrorists to manipulate the public into pressuring a government. The public's fear and nuclear phobia are exacerbated by the media coverage of the terrorist act.

Terrorists rely on the media to spread their cause and reach their target audience. The duration of the media coverage is important. The longer the terrorist group maintains media coverage the longer it has to spread its agenda to the target society. The coverage increases the public panic and demonstrates that the government can not protect society from such activities. The media has the responsibility to keep the public informed. Yet, the media inadvertently becomes a terrorist pawn as they attempt to provide adequate coverage of the act.

The terrorist act feeds on the media coverage which exacerbates the nuclear fear, which in turn, favors the terrorists objectives. These casual links become a vicious cycle which feeds upon itself and subsequently undermines the security of the United States. The cycle can be easily broken in two places. First, the media must try must not allow themselves to inadvertently aid the terrorist's objectives. There is a fine line between informing the public and increasing the fears of the public. The media problem may be impossible to completely solve, but responsible media organizations are cooperative with the U.S. government when dealing with terrorist incidents.[34] Second, an aggressive public awareness program concerning nuclear energy, nuclear medicine, the effects of ionizing radiation, and the risks of cancer must be instituted. The information presented to the public must provide both the positive and negative aspects of the atom. A one sided discussion is conducive to increasing the fear and distrust of the general public, rather than decreasing the fear and distrust.

D. TECHNICAL ASPECTS OF RADIOLOGICAL WEAPONS

Nuclear isotopes are used in a wide range of activities: nuclear weapons, nuclear reactors, industrial applications, food processing, and medical treatment. Hundreds of isotopes are used in the aforementioned fields. The best isotopes to actually produce a

[34] A discussion of the media's role in terrorism can be found in Yonah Alexander and Richard Latter, eds., Terrorism and the Media: Dilemmas for Government, Journalists and the Public (New York: Brassey's Inc., 1990) and Harold J. Vetter and Gary R. Perlstein, Perspectives on Terrorism (Pacific Grove: Brooks/Cole Publishing Company, 1991).

real effect to a person's health are the isotopes with a short half life. The shorter the half life, the greater the specific activity with the implication of a greater amount of ionizing radiation in a short period of time. Isotopes that emit a combination of gamma and alpha or beta particles are the most useful for a terrorist. The gamma particles can produce effects from outside the body, while alpha and beta particles produce the most damage once inside the body. The greatest risks of increased cancer and adverse health effects occur after the inhalation or ingestion of isotopes that emit alpha or beta particles.

The following radionuclides are isotopes of choice for a radiological weapon: americium-241, strontium-90, iodine-131, cobalt-60, cesium-137, uranium-235, uranium-238, and plutonium-239. Irradiated reactor fuel assemblies (spent fuel rods) are also an ideal choice for radiological weapons.[35] These radionuclides were chosen because of their availability, particle emission, and half life. The technical aspects of the isotopes deal with the maximum yearly intake of radionuclides allowed by U.S. law for occupational workers. The following three tables summarize the technical characteristics of the eight selected radionuclides for terrorism.

[35] The selection of isotopes was based upon the number of over lapping uses in industry, nuclear power, and the medical field; half-life of the isotopes; and the combination of gamma, alpha, and beta particle emissions. Irradiated reactor fuel assemblies were chosen because of the sheer volume of spent fuel rods throughout the world and the lack of adequate security measures in many nations of the world that possess nuclear reactors.

Table 1: Half-life, Particle Emission, and Specific Activity

Radionuclide	Half-life	Particle Emission Alpha-Beta-Gamma	Specific Activity (Curies/Gram)
Americium-241	472.2 Years	Alpha & Gamma	3.21 E 00
Cesium-137	30.5 Years	Beta & Gamma	98.50 E 00
Cobalt-60	5.3 Years	Beta & Gamma	1.14 E 03
Iodine-131	8.0 Days	Beta & Gamma	1.24 E 05
Plutonium-239	24,722.2 Years	Alpha & Gamma	6.17 E -02
Strontium-90	27.7 Years	Beta	1.44 E 02
Uranium-235	2.6 E 11 Years	Alpha & Gamma	2.15 E -06
Uranium-238	1.6 E 12 Years	Alpha & Gamma	3.34 E -07

Sources: Half-life and particle emission information was obtained from the Chart of the Nuclides: With Physical Constants, Conversion Factors and Periodic Table, Thirteenth Edition (San Jose: General Electric Company, Nuclear Energy Operations, 1984). The specific activity of the radionuclides was obtained from the CRC Handbook of Materials Science, Volume III: Nonmetallic Materials and Applications (Cleveland: CRC Press, 1975), 319-20.

Table 2: Permissible Oral Intake Amounts

Radionuclide	Oral Intake Permissible quarterly intake (Microcuries)	Oral Intake Permissible yearly intake (Curies)	Oral Intake Permissible yearly intake (Grams)
Americium-241	7.60 E 00	3.04 E -05	9.47 E -06
Cesium-137	3.00 E 01	1.00 E -04	1.02 E -06
Cobalt-60	9.80 E 01	3.92 E -04	3.44 E -07
Iodine-131	4.00 E 00	1.60 E -05	1.30 E -10
Plutonium-239	9.00 E 00	3.60 E -05	5.83 E -04
Strontium-90	8.00 E -01	3.20 E -06	2.22 E -08
Uranium-235	7.40 E 00	2.96 E -05	13.80 E 00
Uranium-238	1.20 E 00	4.80 E -06	14.37 E 00

Sources: The permissible quarterly intake of radionuclides was obtained from the CRC Handbook of Chemistry and Physics, 76th Edition 1995-1996 (New York: CRC Press, 1995), Chap 16, 27-33. The permissible intakes are recommended by the NCRP and ICRP for occupational exposure. These recommendations can be found in NBS Handbook 69: Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure (Washington: U.S. Government Printing Office, 1959); NCRP Report No. 32: Radiation Protection in Education Institutions (Washington: NCRP Publications, 1966); and ICRP Publication 60: 1990 Recommendations of the International Commission on Radiological Protection (London: Pergamon Press, 1991).

Table 3: Permissible Inhalation Amounts

Radionuclide	Intake by Inhalation Permissible quarterly intake (Microcuries)	Intake by Inhalation Permissible yearly intake (Curies)	Intake by Inhalation Permissible yearly intake (Grams)
Americium-241	3.80 E -03	1.52 E -08	4.74 E -09
Cesium-137	4.00 E 01	1.60 E -04	1.62 E -06
Cobalt-60	2.00 E 02	8.00 E -04	7.02 E -07
Iodine-131	5.30 E 00	2.12 E -05	1.71 E -10
Plutonium-239	1.10 E -03	4.40 E -09	7.10 E -08
Strontium-90	7.30 E -01	2.92 E -06	2.02 E -08
Uranium-235	2.90 E -01	1.16 E -06	0.54 E 00
Uranium-238	4.50 E -02	1.80 E -07	0.64 E 00

Sources: The permissible quarterly intake of radionuclides was obtained from the CRC Handbook of Chemistry and Physics, 76th Edition 1995-1996 (New York: CRC Press, 1995), Chap 16, 27-33. The permissible intakes are recommended by the NCRP and ICRP for occupational exposure. These recommendations can be found in NBS Handbook 69: Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and Water for Occupational Exposure (Washington: U.S. Government Printing Office, 1959); NCRP Report No. 32: Radiation Protection in Education Institutions (Washington: NCRP Publications, 1966); and ICRP Publication 60: 1990 Recommendations of the International Commission on Radiological Protection (London: Pergamon Press, 1991).

Table one indicates that the eight selected isotopes meet the criteria of a short half-life, multiple particle emission, and a high specific activity with the implication of a greater amount of ionizing radiation in a short period of time. The greater the amount of ionizing radiation, the greater the chance of increasing the risk of cancer. The Nuclear Regulatory Commission permissible quarterly intake of radionuclides is based upon the maximum permissible dose for occupational exposure.[35] The maximum amount of

[35] The occupational maximum permissible dose is five rem per year. This dose is above the normal dose of three hundred millirem per year received from normal background radiation.

radionuclides in grams was calculated by multiplying the specific activity of the isotope by the permissible yearly intake. Tables two and three indicate that only a very small amount of nuclear material is required to obtain an exposure greater than the U.S. occupational maximum permissible dose. This exposure will increase an individual's risk of cancer and reinforce their nuclear phobia.

The doses indicated by tables two and three are not acute doses of ionizing radiation; they are all in the sub-clinical range. This range is zero to one hundred rems, which is well within the natural amount that everyone on earth receives each year. It is highly improbable that a radiological weapon used by terrorists could immediately disperse enough material, of optimal particle size, to cause an ionizing radiation exposure in the therapeutic range of one hundred to one thousand rems.[36] If goal was to immediately produce a massive number of deaths, then a nuclear, chemical, or biological weapon would be a better choice. However, if the terrorist's goal is to appear to have the capability to cause a large number of deaths, then a radiological weapon is ideal. The psychological and technical aspects of a radiological weapon make it an excellent choice for terrorists.

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[36] It is possible to produce large scale contamination with a radiological weapon. However, a tremendous amount of nuclear material would be required to produce the contamination. Significant quantities of stolen or diverted nuclear material will draw attention and close scrutiny from government officials. Terrorist organizations will want a radiological weapon that uses a small amount of nuclear material that can diverted or stolen with a minimal chance of detection. The terrorist's goal is to appear to have the ability to produce large scale contamination. Perception is everything when dealing with radiological terrorism.

E. SUMMARY

The United States is committed to deterring WMD and the terrorist organizations who may be determined to use it. The U.S. threat analysis on WMD terrorism should be expanded to include radiological terrorism. Governments need to acknowledge that there is a significant difference between nuclear terrorism and radiological terrorism. Nuclear terrorism is more difficult than radiological terrorism. Precise definitions allow for an accurate threat analysis and realistic resource allocation. Although radiological weapons are not true WMD, they can cause contamination and fear.

Nuclear phobia is well established in the United States and in many societies throughout the world. Nuclear power accidents, such as Three Mile Island and Chernobyl, reinforce the public's fear of the atom. Nuclear phobia and the general risk of cancer gives credibility to the psychological aspect of radiological weapons. Nuclear phobia can be decreased by a public awareness program concerning the atom.

Sub-clinical effects from ionizing radiation will not immediately produce a significant number of deaths, but it is enough for terrorists to tap into the public's fear of anything nuclear. Resulting hysteria will generate a considerable amount of public pressure upon a government. Governments must resist this pressure and not give in to the terrorist demands. Any appeasement will give credibility to the terrorist act.

III. AVAILABILITY OF NUCLEAR MATERIAL

This chapter discusses the availability of nuclear material for radiological weapons and terrorism. The assessment begins with an examination of the types of radionuclides that are used throughout the world; followed by a discussion of the locations of the nuclear material. The accessibility of nuclear material is determined by the physical security of the material. Radionuclides under minimum or questionable security measures will be primary targets for theft and diversion to sub-state actors.

A. USES OF RADIONUCLIDES THROUGHOUT THE WORLD

The general public thinks that nuclear material has only two uses: nuclear weapons and commercial nuclear power. Radionuclides are used in a variety of industries ranging from defense to food preparation. The primary sources of nuclear material are the medical field, commercial industry, food industry, nuclear power plants, naval propulsion reactors, research reactors, and dismantled nuclear weapons fissile material.[37]

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[37] Research reactors are used by both governments and universities around the world.

1. Medical

Nuclear medicine began in the 1950's. Radionuclides are primarily used for research and in irradiation treatment of various medical conditions and cancer. Treatment can be from sealed and unsealed sources. Sealed sources are used to externally irradiate the human body; such as in radiotherapeutic treatment. These sources are used in radiology departments, medical clinic x-ray machines, and also to sterilize "medical products, bandages, operating gowns, pharmaceuticals and, in particular, plastic syringes, which would distort with heating and for which fumigants are undesirable."[38] The most common sealed sources are "radium, cobalt-60, iridium-192, and tantalum-182."[39] Unsealed sources are used to internally irradiate the human body. The most common isotopes are "iodine-131, phosphorus-32, yttrium-90, and technetium-99."[40]

Table four summarizes the common isotopes used as tracers in the human body for nuclear medicine investigations and to internally irradiate the human body. Table four demonstrates the extensive use of radionuclides in medical research and nuclear medicine. One must understand that medical organizations, ranging from small medical clinics to major research hospitals, use radionuclides in their day-to-day medical practices.

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[38] The World Nuclear Handbook (New York: Facts on File Publications, 1988), 110.

[39] The World Nuclear Handbook, 95.

[40] The World Nuclear Handbook, 95-6.

Table 4: Common Isotopes Used in Nuclear Medicine

Radionuclide	**Half Life**	**Medical Uses**
Iodine-131	8 days	Adrenal Glands, Kidney, Thyroid, Biological Research
Selenium-75	121 days	Adrenal Glands, Pancreas, Parathyroid Glands, Tumors, Clinical Measurements
Technetium-99	6 hours	Alimentary Tract, Biliary Tract, Bones and Joints, Brain, Heart, Kidney, Liver, Lymph-nodes, Lungs, Marrow, Parathyroid Glands, Salivary Glands, Spleen, Thyroid, Biological Research
Indium-111	2.8 days	Alimentary Tract, Cerebro-Spinal Fluid, Infections, Marrow
Iodine-123	13 hours	Biliary Tract, Brain, Kidney, Thyroid
Thallium-201	73 hours	Heart, Parathyroid Glands
Gallium-67	78 hours	Infections, Tumors
Xenon-133	5.3 days	Lungs, Clinical Measurements
Phosphorus-32	14.3 days	Pain Relief, Prevention of Secondary Spread of Cancer, Biological Research
Iron-52	8.3 hours	Marrow
Yttrium-90	64.1 hours	Biological Research and Clinical Measurements

Sources: Adapted from The World Nuclear Handbook (New York: Facts on File Publications, 1988), 95-105 and Management of Radioactive Wastes Produced by Users of Radioactive Materials, Safety Series No. 70 (Vienna: International Atomic Energy Agency, 1985).

2. Commercial Industry

Industrial uses of radionuclides fall into three areas: industrial and commercial products, power generation sources, and the food industry. Industrial and commercial uses include, but are not limited to, the following areas: insect pest control, plant science, animal science, sterilization, thickness measurements, non-destructive testing of welds,[41] leak testing, gas movement, water movement, silt movement, and commercial products (i.e. smoke detectors and electronic valves).[42] The most common radionuclides used for industrial and commercial purposes are: americium-241, cesium-137, cobalt-60, polonium-210, and plutonium.[43]

Radionuclides have been used as power generation sources since the early 1970's. The isotopes are used to power satellites, Arctic and Antarctic weather stations, lighthouses, navigation buoys, undersea navigation beacons, and communication applications.[44] Table five lists the common radionuclides used as sources of power. Although power generators use relatively small amounts of nuclear material, this use illustrates the extensive applications and industries that have access to radionuclides.

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[41] The World Nuclear Handbook, xiii-xv.

[42] Management of Radioactive Wastes Produced by Users of Radioactive Materials (Vienna: International Atomic Energy Agency, 1985), 9.

[43] Phil Williams and Paul N. Woessner, "The Real Threat of Nuclear Smuggling," Scientific American, January 1996, 42.

[44] William R. Corliss and Robert L. Mead, Power from Radioisotopes (Washington: U.S. Atomic Energy Commission, Division of Technical Information, 1971), 8-33.

Table 5: Radionuclides Used as Power Generation Sources

Radionuclide	**Half-Life** (years)	**Initial Power Density** (watts/gram)
Cobalt-60	5.24	15.8
Strontium-90	28.0	1.0
Cesium-137	30.0	0.22
Promethium-147	2.6	1.8
Thulium-170	0.35	9.6
Polonium-210	0.38	45
Plutonium-238	87.6	2.6-4.0
Curium-244	18.1	13

Source: William R. Corliss and Robert L. Mead, Power from Radioisotopes (Washington: United States Atomic Energy Commission, Division of Technical Information, 1971), 39.

3. Food Industry

Another area for commercial use of sealed sources is the food industry. The most common isotopes are cobalt-60, cesium-137, and carbon-14.[45] Radionuclides are used to neutralize micro-organisms in food products. "Irradiation, in a single one-stage treatment, can destroy contaminants from insects to bacteria, without change in temperature, with no induced radioactivity, and usually with little change in the food taste, texture and nutritional value. A product can be treated through its final lightweight packaging for storage, thus preventing re-contamination."[46] "Effective disinfestation is important for meeting quarantine regulations in international trade."[47]

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[45] The World Nuclear Handbook, 108-9.

[46] The World Nuclear Handbook, 109.

[47] The World Nuclear Handbook, 110.

Radionuclides are also used by the food and agriculture industries in plant science. Cells can be mutated by very low doses of radiation. This mutation is used to breed stronger strains of crops that are more resistant to disease, insects, climate, and can lead to greater rates of food preservation and dehydration.[48] The industrialized countries of the world are more prone to use radionuclides in their food industries. As countries continue to industrialize, there is a higher probability that the abundance of radionuclides in the world will increase.

4. Nuclear Reactor Industry

The nuclear reactor industry is divided into two areas: nuclear power and nuclear propulsion. The nuclear power industry is composed of commercial nuclear power plants and research reactors. The nuclear propulsion industry contains the propulsion reactors used by commercial and naval vessels. All of these reactors can either use uranium or plutonium as their fuel source. The nuclear reactor industry is one of the largest users of radionuclides and one of the largest producers of excess nuclear material. All of this nuclear material is stored in various forms around the world.

The nuclear reactor industry produces waste in the form of spent reactor fuel, high level waste (HLW), transuranic waste (TUR), and low level waste (LLW). Spent reactor fuel is irradiated fuel that is no longer efficient for generating electricity.[49] Spent reactor

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[48] The World Nuclear Handbook, 118.

[49] Spent fuel is produced by commercial light water reactors, non-light water reactors, and fuels associated with university and government research reactors. A complete discussion and summary of radioactive wastes can be found in the U.S. Department of Energy, Integrated Data Base Report-1994: U.S. Spent

fuel includes fuel used by both commercial nuclear power plants and naval propulsion reactors. The normal life span for reactor fuel is three to four years. Spent fuel is highly radioactive and generates large amounts of heat. Thus, heavy shielding is required for handling. Spent fuel is stored in large pools of water at individual nuclear power plants and at commercial reprocessing plants throughout the world.[50]

High level wastes are radioactive wastes generated by the "reprocessing (chemical separation of the uranium and plutonium from other elements) of used nuclear fuel"[51] and spent reactor fuel rods. HLW is highly radioactive, requires heavy shielding, and is normally found in liquid form.[52] It is comprised of numerous radionuclides. The amounts and types of radionuclides present in HLW is dependent upon the life span of the reactor fuel rods and the time after the discharge from the nuclear reactor. The most common radionuclides in HLW are cesium-137, cesium-135, barium-137, strontium-90, americium-241, americium-243, plutonium-239, plutonium-240, uranium-233, uranium-234, palladium-107, and technetium-99.[53] High level wastes can be found worldwide, since all nuclear power plants produce spent fuel.

Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 11, Prepared by Oak Ridge National Laboratory, September 1995.

[50] The Nuclear Waste Primer (Washington: League of Woman Voters Education Fund, 1993), 22.

[51] The Nuclear Waste Primer, 21.

[52] The Nuclear Waste Primer, 21-2.

[53] International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research, Plutonium: Deadly Gold of the Nuclear Age (Cambridge: International Physicians Press, 1992), 114.

Transuranic waste "comes primarily from the reprocessing of spent fuel and use of plutonium in the fabrication of nuclear weapons."[54] The U. S. Department of Energy defines TUR as "waste that is contaminated with alpha-emitting transuranic (TUR) (i.e., atomic numbers greater than 92) radionuclides with half-lives greater than twenty years and in concentrations in excess of one hundred nanocuries per gram."[55] Limited shielding is required to contain the alpha particles when handling TUR.

Low level waste is defined "not by what it is, but by what it is not."[56] LLW includes all radioactive waste not classified as HLW, TUR, uranium mill tailings, or spent nuclear fuel. LLW has short lived radionuclides and low levels of radioactivity. Although there are low levels of radioactivity, shielding is required to handle the wastes. LLW is produced by nuclear power plants, government laboratories, research reactors, hospitals, and industrial plants throughout the world.[57]

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[54] The Nuclear Waste Primer, 22.

[55] A Curie is equal to 3.70 E10 Becquerel. A Becquerel is equal to one disintegration per second. U.S. Department of Energy, Integrated Data Base Report-1994, 75.

[56] U.S. Department of Energy, Integrated Data Base Report-1994, 3.

[57] The Nuclear Waste Primer, 23.

5. Nuclear Weapons

Nuclear weapons contain either or both highly enriched uranium and plutonium.[58] The most common and highly recommended radionuclides for nuclear weapons are uranium-235 and plutonium-239.[59] The nuclear weapon casing provides the required shielding for the uranium and plutonium in the weapon; therefore no additional shielding is required to handle the weapon.

Dismantled nuclear weapons that need to be permanently disposed of contain direct-use nuclear materials. Direct-use nuclear material is composed of plutonium or highly enriched uranium that has not been exposed to radiation or separated from highly radioactive materials.[60] Once these nuclear materials are removed from the nuclear weapons, the material is stored in small, shielded containers. The removed nuclear material will eventually be destroyed or converted into fuel for commercial nuclear power reactors.

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[58] Highly enriched uranium (HEU) is uranium that is enriched above twenty percent in the uranium-235 isotope.

[59] Fissile material is an isotope that readily undergoes fission (splits into two or more lighter elements, thereby releasing energy) after absorbing neutrons of any energy. Fissile materials can undergo self-sustaining nuclear chain reactions, in which the neutrons released in fission reactions will themselves induce additional fission reactions. Fissile isotopes include uranium-233, uranium-235, and plutonium-239. A complete discussion of fissile material and nuclear weapon design can be found in Graham T. Allison, Owen R. Cote, Jr., Richard A. Falkenrath, and Steven E. Miller, Avoiding Nuclear Anarchy: Containing the Threat of Loose Russian Nuclear Weapons and Fissile Material (Cambridge: MIT Press, 1996), 203-28.

[60] Report to Congressional Requesters, Nuclear Nonproliferation: Status of U.S. Efforts to Improve Nuclear Material Controls in Newly Independent States, GAO/NSIAD/RCED-96-89 (Washington: U.S. General Accounting Office, 8 March 1996), 2.

Current weapon dismantlement activities, which are primarily a result of START I and II, between the United States and the Russian Federation are providing and will continue to provide hundreds of tons of fissile material to be disposed of permanently. One must understand that weapons-grade fissile material is not required for radiological devices, but it can be used in the same manner as other nuclear material to produce radiological weapons. Increasing the amount of fissile material, such as from dismantled nuclear weapons, increases the chances that the material can be diverted or stolen.

B. LOCATIONS OF RADIONUCLIDES THROUGHOUT THE WORLD

Radionuclides have a multitude of legitimate uses throughout the world. Thousands of people benefit from the medical uses of nuclear material, relatively inexpensive electrical power provided by nuclear power plants, and greater crop yield because of fewer cases of spoilage and genetic breeding through cell mutation by irradiation. All of the aforementioned examples of radionuclide uses are for the purpose of benefiting mankind. The next question in assessing the threat of radiological weapons is to determine what countries throughout the world have industries that use radionuclides. It must be noted that the scope of this study is not to methodically list every facility in the world that uses radionuclides, but to show the extent to which radionuclides have reached the far corners of the world.

1. Non-Nuclear Power Industries

The non-nuclear power industries are the medical industry, food industry, and the industrial commercial industries. Every country in the world has at least one hospital or medical clinic with a radiology department. Obviously there are countries, such as the United States, Germany, and Japan, that have hundreds of medical facilities that use radionuclides. The major industrialized countries, such as the G-7 countries, have extensive commercial facilities with industrial applications for radionuclides.[61] These industries range from the flat glass industry to mining to food processing plants. Almost every country in the world has radionuclide industries with varying amounts of nuclear material.

2. Nuclear Reactor Industries

The commercial nuclear power industry spread throughout the world primarily through the U. S. Atoms for Peace Program in the 1950's. Today there are hundreds of reactors used for research, commercial power, and propulsion of naval vessels. The nuclear support facilities, such as reprocessing plants and enrichment facilities, have developed alongside the nuclear power programs of the world. Table six summarizes the extent of the nuclear reactor industry in the world today. A detailed summary can be found in Appendix A.

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[61] An example of the magnitude of radionuclide use in industry can be seen on the Kola Peninsula. The Kola Peninsula has more than 9,352 radioactive sources distributed among 39 civilian companies and institutions. Source is Thomas Nilsen and Nils Bohmer, Sources to Radioactive Contamination in Murmansk and Arkhangel'sk Counties, Bellona Report Volume 1 (Norway: Bellona Foundation, 1994), 132.

Table 6: Total Nuclear Reactor Industries of the World

Country	Operating Power Reactors	Operating Research Reactors
North & South America	136	102
Western Europe	150	75
Eastern Europe	60	59
Africa & Middle East	2	11
Asia & Pacific	63	55
World Total	**411**	**302**

Presently, the five declared nuclear weapon states are the only countries that use nuclear reactors for propulsion of naval vessels. These vessels range from submarines to ice breakers. These propulsion reactors contribute high level waste, in the form of spent fuel rods, to the nuclear waste management systems of the five nuclear weapon states.

Nuclear wastes associated with nuclear propulsion and weapons programs have accumulated alongside the respective nuclear power programs. There is a significant amount of nuclear high level waste in the world today and these inventories will continue to grow in the future. Table seven shows the significant amount of high level nuclear waste that is projected for the year 2000.

Table 7: Projected High Level Waste Inventories for Selected Countries by the Year 2000

Country	Amount
Canada	27,000 metric tons spent fuel
Sweden	5,600 metric tons spent fuel
France	2,000 cubic meters HLW
Germany	3,300 cubic meters HLW
Switzerland	200 cubic meters HLW
United Kingdom	1,280 cubic meters HLW
United States	340,600 cubic meters HLW

Sources: Adapted from U.S. General Accounting Office, Report to the Honorable Richard H. Bryan, U.S. Senate, Nuclear Waste: Foreign Countries' Approaches to High-Level Waste Storage and Disposal (GAO/RCED-94-172, 04 August 1994) and U.S. Department of Energy, Integrated Data Base Report-1994: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics, DOE/RW-0006, Rev. 11, Prepared by Oak Ridge National Laboratory, September 1995.

3. Nuclear Weapons

There are five declared nuclear weapon states and three "de facto" nuclear weapon states.[62] The total number of nuclear weapons in the world is in the tens of thousands. The nuclear weapon programs have significant infrastructures supporting the various programs and in some instances, the programs are directly tied to the civilian nuclear power programs. The proliferation of nuclear weapons has increased the locations of nuclear material throughout the world, which has increased the opportunities from which sub-state actors can obtain radionuclides.

[62] The three "de facto" nuclear weapon states are Israel, India, and Pakistan.

4. Nuclear Material Smuggling

Many critics of radiological weapons maintain that the nuclear material required for radiological weapons can not be obtained by terrorists. However, they are wrong. "In a world in which drug smugglers routinely move cocaine around the world in amounts of hundreds of kilograms and marijuana in ton quantities and in which European border controls are being dismantled, the task of illicitly moving small amounts of nuclear materials is not very daunting."[64] Currently, the illicit transfer of non-weapons grade nuclear material is being conducted in Europe and the Former Republics of the Soviet Union.[65]

There were fifty-nine cases of smuggled nuclear material on the European continent between 1992-1995. The most notable incident was the 1992 confiscation of one and half kilograms of weapons grade highly enriched uranium.[66] As of March 1996,

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[64] David Kay, "The IAEA," eds. Mitchell Reiss and Robert S. Litwak, Nuclear Proliferation After the Cold War, (Washington: Woodrow Wilson Center Press, 1994), 311.

[65] A comprehensive summary of open source literature concerning the illicit transfer of nuclear materials can be found in the following sources: The non-proliferation data bases located at the Center for Non-proliferation Studies at the Monterey Institute of International Studies, Monterey, CA; Gordon C. Oehler, Director, DCI's Nonproliferation Center, "The Continuing Threat from Weapons of Mass Destruction," Statement for the Record to the Senate Armed Services Committee, 27 March 1996; Monthly Status Report: Illicit Trafficking of Nuclear Materials (Washington: U.S. Department of Energy, Office of Emergency Management, Operations Division, January 1996); Monthly Status Report: Illicit Trafficking of Nuclear Materials (Washington: U.S. Department of Energy, Office of Emergency Management, Operations Division, December 1995); Energy Incident Quarterly, Fall 1995, Vol. 6, No. 1 (Washington: U.S. Department of Energy, Office of Emergency Management, Office of Nonproliferation and National Security, Operations Division, 1995); Energy Incident Quarterly, Spring 1995, Vol. 5, No. 3 (Washington: U.S. Department of Energy, Office of Nonproliferation and National Security, Threat Assessment Division, 1995); and Black Market Trafficking in Nuclear Material, 1993 & 1994 Transactions (Washington: U.S. Department of Energy, Office of Nonproliferation and National Security, Threat Assessment Division, March 1995).

[66] William C. Potter, "Before the Deluge? Assessing the Threat of Nuclear Leakage From the Post-Soviet States," Arms Control Today, October 1995, 9.

there have been eight incidents of illicit transfers of nuclear material.[66] None of the 1995 or 1996 incidents involved weapons grade nuclear material. One must remember that radiological weapons can be produced from non-weapons grade nuclear material. This brief chronology of nuclear material smuggling indicates that it is possible for nuclear material to be diverted or stolen from various facilities around the world and it confirms that nuclear material is accessible to terrorist organizations.

C. PHYSICAL SECURITY OF NUCLEAR MATERIAL

There are varying degrees of physical security for nuclear materials throughout the world. There are international standards, national level requirements per country, and sub-national requirements within many of the respective countries. The degree of regulation and control of the physical security requirements for nuclear material varies by country; ranging from absolute control and security to no security at all.

Although not perfect by any means, the United States is at the high end of the spectrum with the most stringent control and security requirements for nuclear material. Various foreign countries with only research reactors or medical applications for radionuclides are at the far end of the spectrum. It is not the intent of this study to catalog each country's physical security requirements for nuclear material. The intent is to demonstrate that if the high end countries, such as the United States and the successor states of the Former Soviet Union, are susceptible to theft and diversion of various types

[66] Oehler, "The Continuing Threat from Weapons of Mass Destruction," 27 March 1996.

of nuclear material, then no country in the world is immune from the possibility of terrorists circumventing physical security requirements and obtaining radionuclides.

1. International Physical Security Requirements

International requirements are regulated and inspected by the International Atomic Energy Agency (IAEA).[67] The IAEA's security concerns are over material control, accounting, containment, surveillance, and verification procedures. The purpose of IAEA safeguards is to prevent diversion of nuclear material from civilian nuclear power programs and to provide diversion warnings to the international community. The IAEA does not provide for the physical security requirements of the nuclear facilities. Presently, there is "no international organization responsible for establishing or enforcing physical protection standards."[68] These types of physical security are the responsibility of the individual governments of countries possessing nuclear materials.

The IAEA has developed physical security guidelines for member states.[69] These guidelines are mandatory for those countries that are signatories to the 1982 Convention on the Physical Protection of Nuclear Material. However, the IAEA does not enforce,

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[67] A comprehensive discussion of the International Atomic Energy Agency can be found in U.S. Congress, Office of Technology Assessment, Nuclear Safeguards and the International Atomic Energy Agency, OTA-ISS-615 (Washington: U.S. Government Printing Office, June 1995). Additional information concerning international standards and safety of radiation sources can be found in International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources (Vienna: International Atomic Energy Agency, 1994).

[68] Report to Congressional Requesters, Nuclear Nonproliferation: U.S. International Nuclear Materials Tracking Capabilities Are Limited, GAO/RCED/AIMD-95-5 (Washington: U.S. General Accounting Office, 27 December 1994), 11.

[69] These guidelines can be found in the Convention on the Physical Protection of Nuclear Material (Vienna: International Atomic Energy Agency, 1982).

nor inspect these minimum security guidelines. The guidelines are used primarily by the IAEA and the United States in assessing foreign countries' physical security systems.[70]

2. National and Sub-National Level Physical Security Requirements

National and sub-national level requirements for physical security of nuclear material varies widely throughout the world. These requirements cover the nuclear facilities, the types of nuclear material used throughout the various industries, nuclear waste storage sites, transportation requirements, and nuclear weapons.[71] The United States and the republics of the Former Soviet Union (FSU) are by no means perfect in protecting their nuclear material from theft or diversion.

a. United States

At the national level, physical security requirements is the responsibility of the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC). Security requirements for nuclear weapons are controlled by the Department of Defense. The NRC has the authority to delegate responsibility of regulating radionuclides to the state level. Each level of delegation adds one more varying degree of control and

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[70] U.S. General Accounting Office, Nuclear Nonproliferation: Tracking Capabilities Limited, 11.

[71] Transportation concerns deal with the transport of nuclear material between facilities domestically and internationally. Theft of the nuclear material could occur during transport by truck, rail, air, and sea. A summary of the issues involved can be found in Report to the Chairman, Committee on Governmental Affairs, U.S. Senate, Nuclear Nonproliferation: Japan's Shipment of Plutonium Raises Concerns About Reprocessing, GAO/RCED-93-154 (Washington: U.S. General Accounting Office, 14 June 1993) and Shipments of Nuclear Fuel and Waste ... Are They Really Safe?, DOE/EV-004 (Washington: U.S. Department of Energy, Division of Environmental Control Technology, Transportation Branch, October 1977).

enforcement of security requirements. Material accounting and control is heavily emphasized to deal with the immense radionuclide applications in the United States. However, DOE and the NRC are too small to meticulously track and monitor every industry and institution using radionuclides.

The top U. S. physical security systems range from three tier perimeter fence systems surrounding nuclear facilities to closed circuit television cameras coupled with intrusion detection systems to monitor access to nuclear material. The low end of the systems rests with the material accounting programs to track the use and disposal of radionuclides. Concerns over lax security systems must be directed toward civilian industry, nuclear waste storage sites, medical facilities, and university research reactors. The security violations include, but are not limited to, the following examples: health violations, environmental violations, improper disposal of radionuclides and radioactive waste, and improper storage.[72]

Despite the seemingly high level of physical security systems for U.S. nuclear material, there have been thefts of the nuclear material from the various U.S. inventories. "The General Accounting Office of the United States reports that from 1955-1977, '...unaccounted for special nuclear materials totaled in the thousands of kilograms'."[73] Furthermore, "in 1979 a GE employee was arrested for the theft of 150

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[72] A brief overview of the physical security concerns can be found in the following sources: Jon Marcus, "Documents Show Colleges Routinely Mishandled Radioactive Materials," Associated Press, 15 April 1995, Domestic News; Tim Cornell, "Schools Careless With Radiation," Boston Herald, 15 April 1995, 4; and "NRC: Schools Lax on Nuke Waste," Associated Press Online, 15 April 1995.

[73] CDR J.K. Campbell, "Loose Nukes, Networks, and Minds, " Unpublished Research Paper (Monterey: Naval Postgraduate School, March 1996), 2.

pounds of uranium. In that same year, two other individuals were arrested by federal agents in connection with the seizure of 5000 pounds of stolen uranium."[74] The wide range of radionuclide use coupled with the possibility of lax security procedures in various U.S. industries sets the stage for possible theft or diversion of radionuclides for terrorist use.

b. Former Soviet Union

"Russia's nuclear material inventory - distributed over more than 50 sites - is estimated to consist of 1,100 to 1,300 tons of [highly enriched uranium] HEU and 165 tons of separated, weapon-usable plutonium."[75] The breakup of the Soviet Union resulted in the collapse of the centrally controlled physical security systems designed to protect its nuclear material. Today, the new republics of the Commonwealth of Independent States (CIS) must rebuild a majority of those security systems.

The USSR relied upon closed cities with strong internal security measures to protect their nuclear material. [76] These closed cities had secure perimeters, large numbers of troops protecting the facilities, and were under heavy scrutiny of the KGB. The opening of the closed cities resulted a variety of inadequate physical security

[74] Campbell, "Loose Nukes," 3.

[75] Potter, "Before the Deluge?," 12.

[76] The nuclear material includes spent reactor fuel from nuclear weapon production plants, spent fuel from naval propulsion reactors, fresh fuel for propulsion reactors, and high level radioactive wastes.

measures: no perimeter fences, inadequate tamper proof seals, no intrusion detection devices, lack of closed circuit television cameras, no base line inventory of nuclear materials, no vehicle barriers, lack of adequate communications between guardposts, inadequate storage facilities for dismantled nuclear weapons, poor material control and accounting procedures, and a shortage of adequate nuclear waste disposal facilities.[77]

These security problems are compounded by a lack of financial resources in the CIS; resources which could be used to improve the physical security measures.[78] Nicolai Steinberg, Chairman of the Ukrainian State Committee for Nuclear and Radiation Safety, stated that the "system of physical protection of nuclear material [which was in place] does not meet the standards that currently exist elsewhere in the world."[79]

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[77] A comprehensive summary of minimum security measures in the Former Soviet Union can be found in the following sources: Report to Congressional Requesters, Nuclear Nonproliferation: Status of U.S. Efforts to Improve Nuclear Material Controls in Newly Independent States, GAO/NSIAD/RCED-96-89 (Washington: U.S. General Accounting Office, 8 March 1996); Report to the Honorable Bob Graham, U.S. Senate, Nuclear Safety: Concerns With Nuclear Facilities and Other Sources of Radiation in the Former Soviet Union, GAO/RCED-96-4 (Washington: U.S. General Accounting Office, 7 November 1995); Frank von Hippel, "Fissile Material Security in the Post-Cold-War World," Physics Today, June 1995, 26-31; Pearl Marshall, "Russian Weapons Plutonium Storage Termed Unsafe by MINATOM Official," Nucleonics Week, Vol. 35, No. 17, 28 April 1994, 1; Oleg Bukharin and William Potter, "Potatoes Were Guarded Better: Stealing Nuclear Fuel From the Storage Building at Sevmorput Was - and May Still Be - Easy," Bulletin of the Atomic Scientists, Vol. 51, No. 3, May 1995, 46-50; Oleg Bukharin, The Threat of Nuclear Terrorism and the Physical Security of Nuclear Installations and Materials in the Former Soviet Union, Occasional Paper No. 2 (Monterey: Monterey Institute of International Studies, Center for Russian and Eurasian Studies, August 1992); William C. Potter, "Viewpoint: Nuclear Insecurity in the Post-Soviet States (Congressional Testimony)," The Nonproliferation Review, Spring-Summer 1994, 61-65; and Charles Hecker, "Fears Over Russia's Decaying Nuclear Subs," San Francisco Chronicle, 14 February 1996, A8. Photographs depicting inadequate storage of spent reactor fuel can be found in Thomas Nilsen, Igor Kudrik, and Alexandr Nikitin, Zapadnaya Litsa, Bellona Working Paper No. 5: 1995 (Norway: Bellona Foundation, 29 November 1995).

[78] Nuclear facilities refers to all radionuclides applications (industrial, medical, agriculture, commercial products, and defense) in the Former Soviet Union.

[79] William C. Potter, Emily Ewell, and Elizabeth Skinner, "Nuclear Security in Kazakhstan and Ukraine: An Interview With Vladimir Shkolnik and Nicolai Steinberg," The Nonproliferation Review, Fall 1994, 47.

The lack of adequate physical security measures has directly contributed to the actual incidents of nuclear smuggling from the FSU, which may also contribute to the illicit transfer of radionuclides to various terrorist organizations. Mikhail Barsukov, Director of the Federal Security Service, has stated that it is "quite possible for terrorists to seize weapons of mass destruction such as nuclear weapons, other radioactive materials and hazardous chemicals."[80] Therefore, the FSU may be a target for terrorists and therefore can be considered as the number one source for radionuclides in the world.

D. SUMMARY

Radiological weapons use nuclear material that is abundant throughout the world. Numerous industries, such as medical, agriculture, industrial, commercial, and defense, use a wide range of radionuclides in their day to day operations. These radionuclides are under a spectrum of physical security systems. The spectrum ranges from extremely tight physical controls to questionable security measures. Thus, radionuclides are accessible to indigenous and determined terrorist organizations. Nation-states, such as the United States and the Russian Federation, are not immune from theft and diversion. The CIS can be considered as the number one source for the illicit transfer of nuclear materials.

[80] "Russian Security Chief Admits Nuclear Terrorism Danger," Xinhua General News Service, 27 February 1996.

IV. MOTIVATIONS AND SCENARIOS

The current terrorism debate is whether or not terrorists will use WMD. However, WMD terrorism can not be simply categorized as demand or no demand because radiological weapons can be attractive to both sides of the debate. Radiological devices allow terrorists to operate on the threshold of causing enough casualties to obtain their agenda, yet not lose either internal or external support for their organization.

Coordinated and effective responses can only be developed after determining how terrorist organizations would employ radiological weapons. The nuclear material discussed in chapter two can be effective radionuclides for radiological terrorism. The first widely publicized act of radiological terrorism and seven radiological dispersal scenarios are examined in this chapter.

A. ATTRACTIVENESS OF RADIOLOGICAL WEAPONS

The primary objective of a terrorist group is to coerce a government to meet their political, military, or economic agenda. Terrorists use violence or the threat of violence as their mechanism to obtain a change in governmental policy. The optimal terrorist act uses minimum force to produce maximum fear. Radiological weapons or any other WMD give non-state actors the capacity to carry out a widespread terror campaign. The question remains “will terrorists use WMD?” There are two views of WMD terrorism: no demand for WMD and demand for WMD.[81] The demand for radiological weapons incorporates both views of WMD terrorism.

1. No Demand for WMD

The view that terrorists will not use WMD is based upon Brain Jenkins' statement that "terrorists want a lot of people watching, not a lot of people dead."[82] The use of WMD will produce excessive collateral damage and cause a severe reaction in both the target audience and the government. The reactions could lead to a loss of internal and external support for the group and could every well lead to the destruction of the terrorist organization. If the organization survived the government retaliation, the political legitimacy of the group would be significantly decreased. Political legitimacy is essential if the organization is to bring about a change in government policy.

The unpredictability of WMD also deters terrorists. Terrorists may be willing to lose a few group members in delivering the weapons; yet a majority, if not all of the group could be lost during the production of the weapon. Furthermore, the moral dilemma of causing wide spread destruction and possibly effecting future generations may be to horrific. Once again, the group must account for the reactions to the act if they are to achieve their objectives.

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[81] The perspective of examining WMD terrorism in economic terms -- demand and no demand -- was developed by Professor Gordon McCormick, Academic Advisor for SOLIC, Naval Postgraduate School, Monterey, CA.

[82] Brian M. Jenkins, "Terrorism Found Rising, Now Almost Accepted; Nuclear Incident Unlikely, RAND Concludes," Washington Post, 3 December 1985, A4.

2. Demand for WMD

The view that terrorists will use WMD is based upon Karl-Heinz Kamp's statement that "the more victims of a terrorist's action, the more likely it is that it will capture the world's headlines."[83] The argument is also supported by two assumptions: (1) the current trend that individual terrorist acts are becoming increasingly more violent will continue and (2) current terrorist tactics and weapons will become routine. Therefore, increasingly violent acts and routinization of weapons will lead to WMD.

Weapons of mass destruction will be used by high risk taking groups that want collateral damage. It is the excessive destruction that will produce the dramatic reaction of the government and reinforce the terrorist's claims to the target audience. The possibility of the organization's destruction is out weighed by the possibility of achieving a significant number, if not all of their objectives with one terrorist act. The act also increases the legitimacy of the terrorists by showing that the organization is a force that can not be ignored.

3. Demand for Radiological Weapons

The appearance or ability to kill or incapacitate a large group of people makes the terrorist's threats and acts of violence more credible. Credible threats allow terrorist organizations to instill widespread fear and panic in the target society. The threat or actual use of a weapon of mass destruction accomplishes that goal. Radiological weapons

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[83] Karl-Heinz Kamp, "An Overrated Nightmare," Bulletin of the Atomic Scientists, Vol. 52, No. 4, July/August 1996, 32.

have the potential to induce more fear and long lasting public panic than conventional weapons.

Terrorists can produce tailor made radiological weapons for a variety of scenarios. The size of area affected, degree of health and environmental hazards produced, and psychological impact can all be controlled by a terrorist organization. Large radiological weapons can contaminate and disrupt large population centers, which makes the weapons attractive from the demand view of WMD. However, small radiological weapons that rely more on the psychological aspects also meets the no demand view of WMD.

Terrorists understand that there is a fine line between using violence to gain support for their cause while simultaneously obtaining their objectives and losing supporters through the mass destruction of the target society. Conventional weapons allow the terrorists to stay a considerable distance from this threshold. The closer a terrorist organization is to the threshold, the higher the payoff in holding a society hostage and obtaining the organization's political and military objectives.

The use of a nuclear, chemical, or biological weapon forces the terrorists to cross the threshold and undermine their cause. Supporters, group cohesion, financial resources, and political opportunity are lost. Therefore, the cost of using true WMD is too great.[84]

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[84] Some terrorist organizations, such as those with apocalyptic views, will not be deterred from using true WMD. The use of true WMD will draw significant media coverage. Non-apocalyptic groups that are fighting for that same media coverage may turn to radiological weapons. Radiological terrorism gives the perception of WMD without crossing the threshold.

Radiological weapons allow terrorists to operate on or near the threshold line. The maximum benefit of nuclear phobia and the potential for significant disruption of society is obtained. Therefore, radiological weapons meet more of the terrorists needs for instilling fear than do conventional weapons and prevents immediate catastrophic damage associated with true WMD. As a result, radiological weapons may become one of the preferred weapons of mass destruction for terrorists.

Terrorist motives for using radiological weapons are similar to those for conventional weapons. Non-state actors could use radiological weapons to blackmail governments for any number of political, social, or military objectives. A terrorist group could hide a radiological weapon in a city and attempt to extort the release of their imprisoned brethren, destabilize a government, demand a large sum of money, or force the withdrawal of military troops from a politically sensitive area, such as Northern Ireland or the occupied territories of Israel.

B. CHOICE ISOTOPES FOR TERRORISTS

An accurate threat analysis must determine the most likely radionuclides terrorists would desire to obtain to manufacture radiological weapons. An optimal radionuclide for radiological terrorism must meet the following criteria. First, a radionuclide will only be useful if it can maintain its radioactivity through the three stages of the terrorist action: (1) the theft of the nuclear material, (2) storage until needed, (3) and well after the deployment of the radiological weapon.[85] The minimum half-life of thirty days will allow ample time for theft, storage, and deployment. Second, a terrorist will want to use an isotope that is used in multiple industries. This will increase the difficulty of authorities tracing the origin of the material. Third, radionuclides must be easily accessible. Radionuclides used in civilian industries have a higher probability of being stolen due to the increased chance of minimum physical security measures.

The choice radionuclides for radiological terrorism are based on the aforementioned criteria, the particle emission and half-life of radionuclides discussed in chapter two, and the availability of nuclear material discussed in chapter three. Eight choice radionuclides are: americium-241, strontium-90, iodine-131, cobalt-60, cesium-137, plutonium-239, uranium-235, uranium-238, and spent reactor fuel rods. These isotopes have the widest applications in both the civilian and defense industries of the world. This nuclear material is accessible as demonstrated by the first widely publicized act of radiological terrorism which used cesium-137.

C. RADIOLOGICAL DISPERSAL SCENARIOS

This thesis thus far has shown that the psychological aspects of radiological weapons are optimal for terrorism. The radionuclides needed for radiological weapons are used in a multitude of industries and they are under various physical security conditions.

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[85] A long half-life for a radionuclide (after the terrorist act has occurred) will increase the probability of a government response to terrorist demands due to the environmental clean-up and public demands concerning health hazards.

The next step in assessing the threat of radiological terrorism is to understand the types of radiological dispersal scenarios that terrorists would use to carry out their agendas. The scenarios must allow the terrorist organization to do the following: (1) contaminate a group of people with either a dose equal to or greater than the annual permissible dose allowed by law or a dose sufficient enough to induce nuclear phobia among the general public, (2) sensational enough to obtain media coverage, and (3) depict the ability for the terrorist to strike anywhere and anytime. The first two criteria are critical for radiological terrorism to be successful. The third criteria is satisfied by simply carrying out the terrorist attack. The number and types of dispersal scenarios are only limited by one's imagination. The scenarios can be applied to the continental United States, its military forces, and its allies.

The first widely publicized act of radiological terrorism and seven dispersal scenarios are examined in this chapter. These scenarios allow the terrorists to attempt to affect a large number of people, gain wide spread media coverage, and tap into the nuclear phobia that pervades the world. The scenarios are grouped into five categories: (1) nuclear reactor sabotage, (2) dispersal by conventional explosives, (3) air dispersal, (4) water dispersal, and (5) combined radiological and chemical weapons. The unique combination of weapons of mass destruction terrorism can yield devastating effects and complicate the government's response to the terrorist threat.

1. First Widely Publicized Act of Radiological Terrorism

Until recently, the idea of terrorists using radiological weapons seemed improbable. The first widely publicized act of radiological terrorism recently occurred in Russia. On 23 November 1995, Chechen separatists buried thirty pounds of radioactive cesium-137 in Moscow's Izmailovsky Park. Shamil Basayev, a Chechen guerrilla leader, wanted to demonstrate to the leaders of Russia that he "could do great damage to Russia if the war over Chechen secession did not end."[86] Basayev repeatedly threatened the Russia government with the use of nuclear and chemical weapons in his terrorist attacks to win Chechnya's independence.[87]

The media played a significant role in disseminating the Chechen separatists threats and conveying to the Russian people the idea that the Russian government can not protect the public from the threat of radiological weapons. Basayev used NTV -- an independent Russian television station -- to instill widespread fear and public panic throughout Russian society. During an NTV television interview, Shamil Basayev "claimed that his followers had packed two similar parcels in explosives and hid them in Moscow, where they could be set off to create 'mini-Chernobyls'."[88] Basayev specifically targeted Russian society and attempted to manipulate Russia's nuclear phobia by instilling fear of another Chernobyl.

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[86] Michael Specter, "Russians Assert Radioactive Box Found in Park Posed No Danger," New York Times, 25 November 1995, A5.

[87] "Five Russian Troops Killed in Chechnya: Federal Command," Agence France Presse, 23 November 1995, International News, 1.

[88] Richard Boudreaux, "Chechen's Fear Tactics Strike at Russia's Heart," Los Angeles Times, 1 December 1995, A5.

The Russian government thwarted Basayev's media campaign. Various Russian officials made televised, public statements to downplay the first act of radiological terrorism in Russia. Aleksandr Mikhailov, of the Federal Security Service, stated that "the first tests showed that beyond one meter from the package there was no serious threat to health. Initial tests show that the package does not pose a serious threat to the environment or health."[90] General Andrei Terekhov, a department chief in the Interior Ministry, stated that "none of the radioactive substances stolen could have been used to make nuclear weapons."[91] General Terekhov's statement refers to the cesium-137 found in Izmailovsky Park, Moscow, as well as all of the nuclear material that has been reported stolen or unaccounted for in the Former Soviet Union.

The Russian government's statements that were issued to quell public fear were more credible than Shamil Basayev's threats and acts of terrorism. Thus, Basayev's terrorist act did not produce the intended result. This may be due to the fact that Russia is still not a completely open society or the Russian people are still conditioned not to question the central authority or they are immune to ecological problems after years of poor nuclear waste management practices. Regardless of the lack of success of the incident, it was a specific attempt to use a radiological weapon to induce widespread terror within Russia.

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[90] Specter, "Russians Assert Radioactive Box Posed No Danger," A5.

[91] "Radioactive Materials Stolen from Urals Mine," Agence France Presse, 24 November 1995, International News, 1.

It is unclear as to where the Chechen separatists obtained the cesium-137, which has both industrial and medical applications. Russian investigators have determined that the cesium could have originated from three sources. The first possible source is a Ural mining enterprise. The day after the Izmailovsky Park incident, the Ural mining enterprise reported that "four small lead containers" had been stolen.[91] The second possible source is "an isotope storage facility in Grozny operated by the Russian firm 'Radon'."[92] The final source is any hospital in the region with a radiology facility. The uncertainty of the origin of the cesium-137 suggests that nuclear material required to produce a radiological weapon can be obtained from a variety of relatively unsecure sources. Although this nuclear material may not have posed a serious threat to Russian society, it does demonstrate the ability of a non-state actor to attempt to hold a population hostage by fear and public panic. The threat of radiological terrorism is real.

2. Nuclear Reactor Sabotage

Nuclear reactor sabotage has traditionally been defined as nuclear terrorism. This classification is incorrect. Nuclear reactor sabotage is radiological terrorism and is a real threat in today's world. Everyone fears another Chernobyl disaster. This fear is genuine due to the real health effects that can be produced by a nuclear accident on the scale of the

[91] "Radioactive Materials Stolen from Urals Mine," International News, 1.

[92] Mark Hibbs, "Chechen Separatists Take Credit for Moscow Cesium-137 Threat," Nuclear Fuel, Vol. 20, No. 25, 4 December 1995, 5.

Chernobyl disaster. The notion of sabotage at a nuclear power plant has been reviewed since the beginning of the concerns of nuclear proliferation and terrorists.

Many nuclear power plants have redundant safety features to prevent nuclear accidents and core melt downs. Similar to the varying degree of physical protection standards throughout the world, redundant safety features vary from country to country. Although it is possible for determined terrorists to gain access to a nuclear power plant and commit the precise sabotage required to cause a core melt down, the probability of this type of sabotage is low. Terrorists will need a great deal of inside help from the power plant's employees. It is unlikely to find a great number of disgruntled workers in the key positions that will be required to cause a disaster similar to Chernobyl.

It is possible for terrorists with conventional explosives to destroy a nuclear reactor or high level waste tank that is under minimum physical security measures.[93] These explosives could be delivered by a plane or an automobile. The destruction of a reactor or a high level waste storage container will spread radioactive material over the surrounding area. The effects of the dispersal of radioactive material will depend upon the amount of conventional explosives used in the explosion, the location of the site to a population center or water supply, the size of the radioactive particles upon dispersal, the degree of radioactivity of the stored nuclear material, and the weather conditions.

[93] High level nuclear waste is stored in both liquid and solid form at civilian nuclear power plants throughout the world. The waste is stored at the reactor sites because of the indecision on how to permanently dispose of high level nuclear waste. Until a solution is found and disposal facilities are operational, high level nuclear waste will continue to be stored at nuclear power plants throughout the world.

Susceptibility to nuclear reactor sabotage is a global problem. The United States is generally recognized as possessing the leading standard for physical security measures for nuclear power plants in the world, but no country is perfect. On 7 February 1993, an automobile was driven into Three Mile Island's Nuclear Generating Station, Unit One. The vehicle crashed through a gate and parked inside a protected area next to the door of the turbine building for approximately four hours. Fortunately, it was not a car bomb. The U.S. nuclear industry conducted an extensive review of the physical security measures to prevent sabotage of nuclear power plants.[94] Physical security measures of the nuclear power plants and their respective nuclear waste storage sites are the first line of defense against terrorists and sabotage.

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[94] A comprehensive summary of the issues involved in the susceptibility of United States nuclear power plants to sabotage can be found in the following sources: Wilson Dizard III, "World Trade Center Bombing Prompts New Look at Design Basis Threat," Inside N.R.C., Vol. 15, No. 5, 8 March 1993, 1; Juliana Gruenwald, "NRC Studies Terrorist Threat Against Nuclear Power Plants," U.P.I., 19 March 1993; "Excerpt of the Hearing of the Senate Environment and Public Works Committee, Clear Air and Nuclear Regulation Subcommittee: Rules and Regulations to Protect Commercial Nuclear Power Plants against Terrorism and Sabotage," Federal News Service, 19 March 1993; Matthew L. Wald, "U.S. examining Ways to Protect Nuclear Plants Against Terrorists," New York Times, 23 April 1993, A24; Matthew L. Wald, "A-Plants Warned to be Wary of Truck Bombs," New York Times, 1 July 1993, A15; Jeff Leeds, "U.S. Panel's Move to Upgrade A-Plant Security Draws Fire," Los Angeles Times, 26 July 1994, A5; "U.S. Nuclear Regulatory Commission Proposes Amendments to Physical Security Requirements for Nuclear Power Plants," U.S. Newswire, 4 November 1994; "Threat of Terrorism Debated," Engineering News-Record, Vol. 232, No. 9, 28 February 1994, 15; Matthew L. Wald, "How does the World look Through the Eyes of Aspiring Terrorists?," New York Times, 6 March 1994, A3; Max Baucus, " Protect Nuclear Plants from Sabotage," Congressional Press Releases, 16 March 1994; "NRC Revises Protections for Sabotage by Car Bomb," Nuclear News, August 1994, 26; Kathleen Hart, "NCI Wants More Information About Scope of Final Truck-Bomb Rule," Inside N.R.C., Vol. 16, No. 16, 8 August 1994, 16; and Bernard Stapleton, "Maximize the Margin for Sabotage Safety; Radiological Sabotage in Nuclear Reactors," Security Management, Vol. 38, No. 9, September 1994, 62.

3. Conventional Explosives

Radiological weapons can be dispersed by conventional explosives. These conventional means can range from complex bombs to the ingredients used in the Oklahoma City Federal Building bombing. The radionuclides will be dispersed by the detonation of explosions and will not immediately kill large numbers of people. It will contaminate people in the immediate area to an amount of radiation greater than the occupational limit allowed by law, which will increase the risk of cancer. The largest numbers of immediate casualties from the radiological weapon will be those people directly affected by the blast of the explosion.

The responding emergency teams -- police, fire, and medical personnel -- will help contribute to the dispersal of the material. The material will be picked up on the response teams' clothing and shoes as they work around the bombed area. The nuclear material will be tracked not only throughout the site, but also through the city and the area hospitals. This can be an extremely effective dispersal method if terrorists do not disclose to the media the presence of a radiological weapon until after the weapon is detonated and the response teams and clean up crews have arrived on scene. Numerous people and a significantly large area will be contaminated. This will complicate both the clean up effort and the government response to the terrorist action, incite public panic based upon society's nuclear phobia, and overwhelm medical centers as they scrambled to examine the influx of people claiming to be contaminated. A city could possibly shut down.

The situation can be further complicated if the terrorists claimed that it was a nuclear weapon that was detonated. The government experts will have to determine if the weapon was a fizzled nuclear weapon, a radiological weapon, or a hoax. Public hysteria will be increased in the surrounding area. This type of dispersal scenario is completely plausible if one imagines that a radiological weapon was detonated along with the vehicle bombs used in the World Trade Center and the Oklahoma City Federal Building bombings.

4. Air Dispersal

It is possible to "grind up" nuclear material so it can be dispersed in the air. Information concerning the safe handling of hazardous materials is widely available in open source literature. There are vast numbers of individuals throughout the world who safely work with radionuclides everyday. Thus, the knowledge, technology, and expertise to handle and "grind up" nuclear material is available to sub-state actors.

Many of the radionuclides that are used in civilian industry are in sealed sources that are in small, portable containers. It will not be difficult to handle these materials while attempting to grind them up. The hardest nuclear material to handle will be spent nuclear fuel rods, which are highly radioactive.[95] Spent fuel rods that have been cooling

[95] Information concerning the handling of spent nuclear fuel rods can be found in the following source: W.R. Lyod, M.K. Sheaffer, and W.G. Sutcliffe, Dose Rate Estimates from Irradiated Light-Water-Reactor Fuel Assemblies in Air, UCRL-ID-115199 (Livermore: Lawrence Livermore National Laboratory, 31 January 1994).

for fifteen years or longer can safely be handled without receiving a lethal dose (LD50)[96] of 450 rem if handled from a distance greater than one meter.[97] Handling spent fuel rods requires specific knowledge and expertise so as not to substantially irradiate the individuals handling the material; however, terrorists may not be concerned with the health hazards involved in handling the spent fuel rods.

a. Aerial Vehicles

Ground up nuclear material can be dispersed by aerial vehicles. The amount of material to be dispersed is determined by the size of the vehicle needed to carry out the terrorist act. Two common vehicles that can be used are radio controlled planes and crop dusters. Radio controlled planes are very common and can be purchased for a few thousand dollars.[98] These planes can be purchased with nine foot wingspans and the ability to travel one hundred and fifty miles per hour.[99] Many of these planes can carry payloads and smoke emitting devices. It would be feasible for these small radio controlled planes, which are similar to military unmanned aerial vehicle in size and ability, to be used to disperse nuclear material over a region.

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[96] The definition of LD50 is that if each person within a given population received a specified dose, at least fifty percent would die from the exposure.

[97] Lyod, Sheaffer, and Sutcliffe, Dose Rate Estimates, 1.

[98] Radio controlled plane competitions are quickly becoming the new hobbies for aerial enthusiasts around the world.

[99] "Radio-Controlled Airplane Races on Until Tomorrow," Monterey County Herald, 10 February 1996, C1.

Terrorists can ruin a season's food crop on the scale that occurred following the Chernobyl disaster if they used a crop duster or radio controlled plane to spread nuclear material over a farming region. The contaminated crops will most likely rot before people would purchase the contaminated food. Knowingly ingesting radionuclides is contrary to society's nuclear phobia, fear of the unknown, and perception of cancer. Simultaneous contamination of several farming regions will devastate a country's food supplies and hurt their economy, which could be a very valuable bargaining tool for terrorists.[100] Public outcry combined with the farmers' demands for compensation will require the government to either meet the terrorist demands or retaliate against the terrorist organization. Either way, the target country would suffer.

b. Ventilation Systems

Dispersal by a ventilation system has the potential to contaminate a large number of people. The building itself and its vast ventilation system ducting will be contaminated. Clean up efforts for the building will be difficult and time consuming. The government and the public, to some degree, will have to decide at what point the clean up effort is complete. The building will shut down for a significant period of time. Terrorists could disrupt entire cities by targeting key locations. These locations can range from financial institutions to transportation centers.

[100] The simultaneous contamination of several farming areas may seem improbable because of the high degree of coordination and the number of resources that would be required to execute the plan. However, state-sponsored sub-state actors or determined terrorist organizations could organize and carry out such a plan. Under estimating a terrorist organization may leave a country vulnerable to terrorist attacks.

5. Water Dispersal

Dispersal of radionuclides in water supplies has been a scenario that has been exacerbated by the media since the first reports of fissile material smuggling from the New Republics of the Former Soviet Union. The typical claim is that only a few ounces of plutonium would kill thousands of people if it was dispersed in a city's water supply. These claims are simply not true. It will require tons of plutonium to get a kilogram of plutonium to stay suspended in a water supply. The dose received by drinking this contaminated water will be less than the annual dose received from natural background radiation.[101] Thus, this type of scenario will not only be logistically infeasible for terrorists to carry out, but it will not meet the criteria of having a dose greater than background radiation.

The criteria could be met by dispersing radionuclides in a small water supplies, such as five gallon water coolers that are common place in today's society. Terrorists can place small amounts of radionuclides in the water bottles and disperse them throughout a city. The terrorist act will have the appearance of being wide spread and effecting a large number of people. Only a small amount of nuclear material is needed to set off geiger counters as emergency crews began the tedious task of determining the extent of the contamination. Public distrust, their perception of the risks involved, and nuclear phobia will all determine the level of public response and demand for government action.

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[101] A summary of the dangers of plutonium in water supplies can be found in Sutcliffe, Condit, Mansfield, Myers, Layton, and Murphy, A Perspective on the Dangers of Plutonium, 7-14.

D. COMBINED RADIOLOGICAL AND CHEMICAL DISPERSAL SCENARIOS

A unique combination of weapons of mass destruction terrorism is to combine radiological weapons with chemical weapons. This combination will yield devastating effects and complicate the government's response to the terrorist threat. The radiological weapon will allow terrorists to tap into society's nuclear phobia, while the chemical weapon will produce the immediate health effects that will reinforce the nuclear phobia and undermine the government's attempts to dispel fears and health risks. Two scenarios using the combination of radiological and chemical weapons. The first scenario involves the aerial dispersal of a radiological weapon along with a cancer causing chemical weapon. The second scenario is to disperse radionuclides in water supplies with an emetic chemical.

1. Air Dispersal of a Combined Weapon

A combined aerial weapon can be a weapon that combines radionuclides and aflatoxin. Aflatoxin is a toxin that will cause cancer within five to ten years of exposure. The knowledge of how to produce aflatoxin is available throughout the world. In fact, Iraq had produced large quantities of aflatoxin, which were weaponized as part of its extensive chemical weapons program.[102] Since aflatoxin is a chemical, it can easily be dispersed from an aerial spray tank. A crop duster, carrying radionuclides in powdered

[102] Kathleen Bailey, "Deterring the Use of Weapons of Mass Destruction" Lecture given at the Naval Postgraduate School on 19 March 1996.

form and spray tanks of aflatoxin, could be used to disperse the combined weapon over a crop region or a city. The radionuclides will play upon the public's nuclear phobia, while the aflatoxin will produce real cancer causing health effects to a large number of people. Chemical weapons and radiological weapons are complementary when used in this type of dispersal scenario.

2. Water Dispersal of a Combined Weapon

Radiological weapons and chemical weapons are not only complementary for air dispersal, but also for water dispersal. Millions of families around the world have syrup of ipecac in their medicine cabinets. Syrup of ipecac is an emetic commonly used to induce vomiting when young children have ingested a poison. Ingestion of a small quantity of syrup of ipecac, such as a tablespoon, will induce vomiting. Ingestion of larger quantities will produce violent vomiting.

Combining a small quantity of radionuclides with syrup of ipecac into a water cooler size water supply is a plausible scenario. [104] The quantity of radionuclides will only have to be large enough to set off a geiger counter. The nuclear material will trigger the nuclear phobia, while the syrup of ipecac will induce vomiting. The vomiting will be associated with vomiting caused by radiation poisoning. The immediate chemical effects will be associated with the nuclear material and increase the public's fear and reactions.

[104] The use of syrup of ipecac in a water dispersal scenario was developed by the author in conjunction with Bill Scott, Department of Energy, Idaho Falls, Idaho, November 1995.

E. SUMMARY

Radiological weapons are superb psychological terror weapons that can complement the psychological aspects of terrorism. Radiological weapons induce more widespread fear and long lasting public panic than conventional weapons, with minimum risk to their personnel and organization. These weapons allow terrorist organizations to operate on the threshold that separates acts of violence from being ineffective in attaining their goals and from being overly devastating so that internal and external support for their cause is lost.

The first widely publicized act of radiological terrorism accomplished three objectives. First, it demonstrated the accessibility of nuclear material to terrorists. Second, the act demonstrated one aspect of how radiological weapons can be employed. Finally, it provided a scenario for other sub-state actors to draw lessons learned and improve future dispersal scenarios.

Many of the dispersal scenarios that can be employed by terrorists can not be effectively deterred, only effective responses to the acts of violence can be prepared. To effectively prepare for all of the possible contingencies, response teams and supporting agencies, such as the intelligence community, must understand likely scenarios to be employed by terrorists. Scenarios must allow a terrorist organization to effectively contaminate a group of people with either a dose equal to or greater than the annual permissible dose allowed by U.S. law or a dose sufficient enough to induce nuclear phobia among the general public. The scenarios need to depict the ability of the terrorist organization to strike anywhere and anytime. The appearance must be that no one is safe. All of the scenarios that were discussed in this chapter meet the aforementioned criteria. Governments throughout the world must be prepared to deal with scenarios ranging from nuclear reactor sabotage to contaminated water supplies.

The hardest scenarios to effectively prepare for are the scenarios involving combined weapons of mass destruction. The combination of chemical weapons with radiological weapons will complicate the government response to the terrorist act, medical assistance to the victims, and the environmental clean up. These challenges are not insurmountable obstacles, but they must be comprehensively examined to ensure a coordinated and effective response to minimize injury and damage. These issues must be examined from the national level down to the local levels. The weakest part of the response will be from those agencies that are unprepared to deal with the situation.

V. CONCLUSION

A. MAJOR FINDINGS

The findings of this thesis are not meant to be alarmist; yet the possibility of terrorists using radiological weapons can not be ignored.. This thesis is a vulnerability assessment concerning radiological weapons and terrorism. The findings of this thesis can be incorporated in the present U.S. resource allocation towards deterring and countering WMD terrorism.

1. New Concern Over Radiological Weapons

The United States is committed to deterring WMD and the terrorist organizations who may be determined to use WMD. The U.S. threat analysis on WMD terrorism must be expanded to include radiological terrorism. Radiological weapons are the niche between conventional weapons and true WMD. These weapons can produce contamination and fear that is conducive to terrorist objectives.

2. Radiological Weapons Produce Contamination and Fear

Nuclear phobia is well established in the United States and in many societies throughout the world. Nuclear power accidents reinforce the public's fear of the atom. The nuclear fear gives credibility to the psychological aspect of radiological weapons.

Sub-clinical effects from ionizing radiation will not immediately produce a significant number of deaths. However, sub-clinical effects are enough for terrorists to tap into the public's nuclear fear. Resulting hysteria will generate a considerable amount of public pressure upon a government. Governments must resist this pressure and not give in to the terrorist demands.

3. Nuclear Material is Accessible: Abundant and Under Minimum Physical Security

Radiological weapons use nuclear material that is abundant throughout the world: medical facilities, agriculture, commercial industry, and defense. These radionuclides are under a spectrum of physical security systems. The spectrum ranges from extremely tight physical controls to questionable security measures. Superpowers, such as the United States and the Russian Federation, are not immune from theft and diversion. The CIS can be considered as the number one source for the illicit transfer of nuclear materials.

4. Radiological Weapons Complement Terrorism

Radiological weapons are superb psychological terror weapons that can complement the psychological aspects of terrorism. Radiological weapons induce more widespread fear and long lasting public panic than conventional weapons, with minimum risk to their personnel and organization. These weapons allow terrorist organizations to operate on the threshold that separates acts of violence from being ineffective in attaining their goals and from being overly devastating so that internal and external support for their cause is lost.

5. Limitless Radiological Dispersal Scenarios

To effectively prepare for all of the possible contingencies, response teams and supporting agencies, such as the intelligence community, must understand the most likely scenarios to be employed by terrorists. The hardest scenarios to effectively prepare for and respond to are those involving the combination of true WMD with radiological weapons. This combination will complicate the government response to the terrorist act, medical assistance to the victims, and the environmental clean up.

B. IMPLICATIONS TO THE INTELLIGENCE COMMUNITY

The findings of this thesis have implications to the U.S. intelligence community. Intelligence plays a vital role in the non-proliferation of weapons of mass destruction and countering terrorism. The intelligence community is essential in assessing the threat posed by radiological terrorism and the U.S. vulnerability to it. Intelligence efforts can be divided into four categories: indications and warning, collection, intelligence cooperation, and lead agency. Improvements in these four categories will increase the U.S. efforts to deter, counter, and respond to radiological threats.

1. Indications and Warning

The indications and warnings discussed in this section are by no means a comprehensive list of indicators to signal that a terrorist organization has the predilection to use weapons of mass destruction. It is a list of indications and warning for those organizations that may be involved in radiological terrorism. The indication and warnings can be divided into five areas: brain trust, education, views, technology investment, and tactics.

The first two indicators, brain trust and education, must be discussed together. The brain trust is a group of individuals with similar educational backgrounds. Radiological weapons are technical weapons. The terrorist organizations need individuals with the requisite backgrounds to locate the nuclear material, safely handle the material, and assemble a weapon that fits the desired dispersal method. The technical brain trust may consist of engineers, physicists, chemists, radiology technicians, nuclear power plant workers, or workers specializing in the waste management of discarded nuclear material. These types of individuals will have the required knowledge on how to locate radionuclides without drawing suspicion to their activities and will have the knowledge on how to handle and transport the material with minimal.[104]

If no brain trust exists or if one needs to be expanded, then one of the easiest ways to accomplish the brain trust is through education. Organizations may encourage or fund members to obtain the required technical backgrounds required for radiological weapons.

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[104] Decreasing the risk of exposing individuals of the terrorist organization to the negative health effects of nuclear material increases the attractiveness of radiological weapons. Organizations will not need individuals willing to sacrifice themselves in assembling, transporting, or detonating the device.

One must remember that crude radiological weapons require a very minimal technical background, if any, to assemble and detonate. Monitoring the types of educational backgrounds that known or suspected sub-state actors may have or be receiving will indicate the degree of capability and sophistication of the organization in carrying out radiological terrorism.

The third indicator is terrorist views. Organizations that border on or use apocalyptic views, such as religious fundamentalists or supremacists, in their literature and rhetoric are excellent candidates not only for using radiological weapons, but all weapons of mass destruction. These organizations may be the most dangerous because of the willingness to sacrifice members of the group in carrying out the terrorist act. Self sacrifice can be used to eliminate the need for a terrorist to have a technical background when dealing with radiological terrorism. If apocalyptic groups begin to use any type of WMD, then other terrorist organizations may have to turn to WMD terrorism to gain the media coverage they desire. Non-apocalyptic groups will desire to use minimum violence with the perception of possessing the capability to conduct widespread death and destruction; therefore, they may turn to radiological terrorism.

The fourth indicator is the investment in radionuclide industries. Organizations that legally own industries that use nuclear material can obtain or divert radionuclides for the purpose of producing radiological weapons. An unknown diversion of material is possible because of the lack of transparency in verification and accountability and inadequate security in radionuclide industries throughout the world. The ease of obtaining nuclear material is particularly true when referring to state-sponsored terrorism. Foreign countries could support or otherwise encourage terrorist organizations to use radiological weapons against the United States and its vital national interests. The ability to monitor radionuclides in foreign countries is far more difficult when those countries have little or no regulations or intent to regulate and closely monitor commercial radionuclide applications.

The final warning sign is tactics. Tactics involves the methods, types of weapons, and risk. Terrorists that are sophisticated in their methods and weapons may eventually innovate to WMD terrorism. Any group that is willing to take large risks and has a higher degree of commitment to their objectives than to personal safety are more inclined to use WMD to obtain their objectives. A high degree of risk taking usually equates to vicious attacks with a high number of causalities.[105] A small amount of WMD can either produce or give the appearance of possessing the capability to produce a large number of causalities.

The five indications and warnings discussed in this section can be added to the present data bases and watch lists used by the intelligence and law enforcement agencies responsible for countering terrorism. These indicators may not spotlight an unknown and determined terrorist. They will provide an excellent indication of terrorist organizations that presently have or are trying to obtain the ability to produce and employ radiological weapons.

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[105] Tactics for possible WMD use were compiled from the following sources: Ron Purver, Strategic Analyst, Chemical and Biological Terrorism: The Threat According to the Open Literature (Canada: Canadian Security Intelligence Service, June 1995), 49-51 and U.S. Congress, Office of Technology Assessment, Technologies Underlying Weapons of Mass Destruction, OTA-BP-ISC-115 (Washington: U.S. Printing Office, December 1993).

2. Intelligence Collection

a. Human Intelligence (HUMINT)

Human intelligence can provide access to sub-state actors that are critical in countering radiological terrorism. HUMINT can not only possibly provide a terrorist organization's intentions or cue additional collection assets, but it could also possibly provide a higher degree of understanding that might be unavailable in technical collection sources. This understanding includes radiological stockpiles, facilities, hardware, dispersal methods, material samples, supply sources, and brain trust.[106]

Non-official cover agents can provide the greatest amount of information concerning the non-proliferation of radiological weapons and terrorism. The proper use of NOCs will allow the Central Intelligence Agency (CIA) to de-emphasize the reliance on foreign nationals and third country nationals to gather intelligence in countries of interest. This will require "new people, new methods, and new technology."[107]

The CIA needs to expand its NOC program into areas, such as "energy companies, import-export firms, banks with foreign branches and high-tech corporations,"[108] nuclear power industry, nuclear waste reprocessing facilities, arms industry, arms control and disarmament verification, international inspection teams,

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[106] Jeffrey T. Richelson, "Can the Intelligence Community Keep Pace with the Threat?" eds. Mitchell Reiss and Robert S. Litwak, Nuclear Proliferation After the Cold War (Washington: Woodrow Wilson Center Press, 1994), 296.

[107] Angelo Codevilla, "The CIA's Identity Crisis: How Central is Central Intelligence?" American Enterprise, Vol. 3 No. 1, Jan-Feb 1992, 30.

[108] Elaine Shannon and Douglas Waller, "Spies for the New Disorder," Time, Vol. 145 No. 7, 20 February 1995, 29.

multilateral science organizations, medical industry, journalism, clergy, and academia. This vast network of non-official cover agents will complement the access available to official cover and overt agents. The intelligence gathered by HUMINT agents will increase the all source collection that is required to counter radiological weapons and terrorism.

b. Open Source Intelligence (OSINT)

Electronic media, databases, libraries, on-line services, and the internet are all open sources that are available to terrorist organizations. There is a tremendous wealth of technical knowledge available from these open sources. An individual can access information on how to produce crude bombs, chemical agents, handle hazardous material, technical manuals, and information concerning terrorism.

Technical information and points of contact concerning any aspect of radiological weapons can be obtained by electronic mail from anywhere in the world. The internet and electronic mail links the world into a single information sphere. "The information revolution has dramatically increased both the quantity and quality of the information available."[110] A terrorist organization can expand its brain trust by simply "surfing the internet" or by electronically corresponding to an individual, who could be located across the globe. The amount of information and ease of accessibility will only increase in the twenty-first century. Maximizing OSINT will benefit analysis,

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[110] Robert D. Steele, "The Importance of Open Source Intelligence to the Military," Intelligence and Counterintelligence, Vol. 8, No. 4, Winter 1995, 464.

operational planning, and enable government agencies to plan effective responses to radiological threats.

3. Intelligence Cooperation

Radiological weapons have the least transparency for verification and acceptability in the international arena because there are no international norms or treaties banning radiological weapons. The lack of transparency means that it may be easier to legally obtain or divert nuclear material than other forms of WMD. The path of least resistance for a terrorist organization may well be the path of least transparency. Countering radiological terrorism may require a tremendous number of resources and assets. The problem of not having enough resources can be overcome by increasing domestic and international cooperation.

Bilateral intelligence cooperation in joint efforts to counter the radiological threat can focus on the smuggling of nuclear material, identifying clandestine radiological programs, and terrorist organizations who train, posses, or employ radiological weapons, supply networks, and counter-terrorism operations. International cooperation will signify that the international community will not condone the use of radiological weapons. Joint efforts will demonstrate the U.S. resolve in preventing the spread of nuclear material and radiological terrorism.

4. Lead Intelligence Agency

The lead U.S. intelligence agency for the nonproliferation of weapons of mass destruction is the Director of Central Intelligence's Nonproliferation Center (NPC). The NPC is "designed to coordinate all of the government's intelligence efforts related to proliferation and to serve as a single point of contact within the community."[111] Centralized tasking is essential to a coordinated and integrated effort against not only radiological weapons, but all WMD. All source collection must maximize HUMINT, OSINT, and international cooperation against radiological weapons.

The Nonproliferation Center has the opportunity to indicate that the United States may be vulnerable to radiological devices if the U.S. continues to downplay these weapons because they can not cause immediate widespread death and destruction. This view point concerning radiological weapons can be changed. The NPC is at the level of bureaucracy that can indicate to the policy makers that radiological weapons are viable weapons for WMD terrorism and that these weapons require adequate attention.

C. AREAS FOR ADDITIONAL RESEARCH

There are three areas, not presented in this thesis, that require additional research. The first area concerns the criteria for WMD terrorism. A comprehensive model, based on tangible variables, needs to be developed to indicate whether or not a terrorist

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[111] Henry Sokolski, "Fighting Proliferation," eds. Roy Godson, Ernest R. May, and Gary Schmitt, U.S. Intelligence at the Crossroads: Agendas for Reform (Washington: Brassey's, 1995), 207.

organization has the predilection to use weapons of mass destruction. This model must provide indicators for all WMD and identify a threshold that can be monitored. The threshold will indicate when the organization has determined that conventional weapons are no longer adequate and that WMD is required to obtain their goals.

The second area is open source collection for the intelligence community. The intelligence community must know exactly what is available from open sources, particularly on-line electronic databases, such as the internet. If the intelligence community does not have comprehensive knowledge of the types of information that is available to terrorists, then a complete and accurate analysis can not be formulated. This thesis is an initial attempt to provide an open source analysis on radiological terrorism.

The final area for additional research is to develop realistic radiological terrorism scenarios that address both the technical aspects of radiological weapons and the psychological terror that is generated by a radiological terrorist act. These scenarios must be rehearsed at all levels of government. Rehearsed scenarios will identify problems in coordination, resource allocation, preparedness, and response times. Overcoming the problems identified in the scenarios will decrease the U.S. vulnerability to radiological terrorism.

APPENDIX: NUCLEAR REACTOR INDUSTRIES OF THE WORLD

Tables eight through twelve summarize the extent of the nuclear reactor industry in the world today. The shaded countries indicate that the country has the technology and at least a pilot program for enriching uranium or processing plutonium. It is these countries that are the concern of the present nonproliferation regime because these programs can be expanded to produce nuclear weapons. Yet, it is the myriad number of unshaded countries that are of particular concern to thhis thesis because it is these countries that have an abundance of radionuclides that could be used to produce radiological weapons.

Table 8: Nuclear Reactor Industries of North and South America

Country	Operating Power Reactors	Fissile Material Production Facilities[1]	Operating Research Reactors
Argentina	2	Enrichment	6
Brazil	1	Enrichment	4
Canada	22	None	9
Chile	0	None	2
Colombia	0	None	1
Jamaica	0	None	1
Mexico	2	None	1
Peru	0	None	3
United States	109	Enrichment & Reprocessing	75
Total for Region	**136**	**N/A**	**102**

Sources: Adapted from Nuclear Research Reactors in the World, Reference Data Series No. 3 (Vienna: International Atomic Energy Agency, December 1994); Nuclear Power Reactors in the World, Reference Data Series No. 2 (Vienna: International Atomic Energy Agency, April 1995); Leonard S. Spector, Mark G. McDonough, and Evan S. Medeiros, Tracking Nuclear Proliferation: A guide in Maps and Charts, 1995 (Washington: Carnegie Endowment for International Peace, 1995); Thomas B. Cochran, William M. Arkin, Robert S. Norris, and Milton M. Hoenig, Nuclear Weapons DataBook: Volume III, U.S. Nuclear Warhead Facility Profiles (Cambridge: Ballinger Publishing Company, 1987); Thomas B. Cochran, William M. Arkin, Robert S. Norris, and Milton M. Hoenig, Nuclear Weapons DataBook: Volume II, U.S. Nuclear Warhead Production (Cambridge: Ballinger Publishing Company, 1987); and U.S. Congress, Office of Technology Assessment, Technologies Underlying Weapons of Mass Destruction, OTA-BP-ISC-115 (Washington: U.S. Government Printing Office, December 1993).

[1] The category "Fissile Material Production Facilities" refers to a country having at least one of the following: (1) pilot plant for uranium enrichment, (2) industrial capability for uranium enrichment, (3) pilot program for plutonium reprocessing, or (4) large scale plutonium reprocessing program.

Table 9: Nuclear Reactor Industries of Western Europe

Country	Operating Power Reactors	Fissile Material Production Facilities	Operating Research Reactors
Austria	0	None	3
Belgium	7	None	4
Denmark	0	None	2
Finland	4	None	1
France	56	Enrichment & Reprocessing	19
Germany	21	Enrichment	21
Greece	0	None	1
Italy	0	Enrichment	5
Netherlands	2	Enrichment	2
Norway	0	None	2
Portugal	0	None	1
Spain	9	None	0
Sweden	12	None	2
Switzerland	5	None	3
United Kingdom	34	Enrichment & Reprocessing	9
Total for Region	**150**	**N/A**	**75**

Sources: Adapted from Nuclear Research Reactors in the World, Reference Data Series No. 3 (Vienna: International Atomic Energy Agency, December 1994); Nuclear Power Reactors in the World, Reference Data Series No. 2 (Vienna: International Atomic Energy Agency, April 1995); Leonard S. Spector, Mark G. McDonough, and Evan S. Medeiros, Tracking Nuclear Proliferation: A guide in Maps and Charts, 1995 (Washington: Carnegie Endowment for International Peace, 1995); Robert S. Norris, Andrew S. Burrows, and Richard W. Fieldhouse, Nuclear Weapons Databook: Volume V: British, French, and Chinese Nuclear Weapons (Boulder: Westview Press, 1994); and U.S. Congress, Office of Technology Assessment, Technologies Underlying Weapons of Mass Destruction, OTA-BP-ISC-115 (Washington: U.S. Government Printing Office, December 1993).

Table 10: Nuclear Reactor Industries of Eastern Europe

Country	Operating Power Reactors	Fissile Material Production Facilities	Operating Research Reactors
Belarus	0	None	4
Bulgaria	6	None	1
Czech Republic	4	None	3
Hungary	4	None	2
Kazakhstan	1	Enrichment	5
Latvia	0	None	1
Lithuania	2	None	0
Poland	0	None	3
Romania	0	None	2
Russia	29	Enrichment and Reprocessing	31
Slovak Republic	4	None	0
Slovenia	1	None	1
Ukraine	9	Enrichment	3
Uzbekistan	0	None	1
Former Yugoslavia	0	None	2
Total for Region	**60**	**N/A**	**59**

Sources: Adapted from Nuclear Research Reactors in the World, Reference Data Series No. 3 (Vienna: International Atomic Energy Agency, December 1994); Nuclear Power Reactors in the World, Reference Data Series No. 2 (Vienna: International Atomic Energy Agency, April 1995); U.S. General Accounting Office, Report to the Honorable Bob Graham, U.S. Senate, Nuclear Safety: Concerns With Nuclear Facilities and Other Sources of Radiation in the Former Soviet Union (GAO/RCED-96-4, 07 November 1995); Leonard S. Spector, Mark G. McDonough, and Evan S. Medeiros, Tracking Nuclear Proliferation: A guide in Maps and Charts, 1995 (Washington: Carnegie Endowment for International Peace, 1995); and U.S. Congress, Office of Technology Assessment, Technologies Underlying Weapons of Mass Destruction, OTA-BP-ISC-115 (Washington: U.S. Government Printing Office, December 1993).

Table 11: Nuclear Reactor Industries of Africa and the Middle East

Country	Operating Power Reactors	Fissile Material Production Facilities	Operating Research Reactors
Algeria	0	Processing	2
Egypt	0	None	1
Ghana	0	None	1
Iran	0	None	2
Israel	0	Processing	2
Libya	0	None	1
South Africa	2	Enrichment	1
Zaire	0	None	1
Total for Region	**2**	**N/A**	**11**

Sources: Adapted from Nuclear Research Reactors in the World, Reference Data Series No. 3 (Vienna: International Atomic Energy Agency, December 1994); Nuclear Power Reactors in the World, Reference Data Series No. 2 (Vienna: International Atomic Energy Agency, April 1995); Leonard S. Spector, Mark G. McDonough, and Evan S. Medeiros, Tracking Nuclear Proliferation: A guide in Maps and Charts, 1995 (Washington: Carnegie Endowment for International Peace, 1995); and U.S. Congress, Office of Technology Assessment, Technologies Underlying Weapons of Mass Destruction, OTA-BP-ISC-115 (Washington: U.S. Government Printing Office, December 1993).

Table 12: Nuclear Reactor Industries of Asia and the Pacific

Country	Operating Power Reactors	Fissile Material Production Facilities	Operating Research Reactors
Australia	0	None	2
Bangladesh	0	None	1
China	3	Enrichment & Reprocessing	13
India	9	Enrichment & Reprocessing	6
Indonesia	0	None	3
Japan	49	Enrichment & Reprocessing	19
North Korea	1	None	1
South Korea	0	None	4
Malaysia	0	None	1
Pakistan	1	Enrichment & Unconfirmed Processing	2
Philippines	0	None	1
Thailand	0	None	1
Vietnam	0	None	1
Total for Region	**63**	**N/A**	**55**

Sources: Adapted from Nuclear Research Reactors in the World, Reference Data Series No. 3 (Vienna: International Atomic Energy Agency, December 1994); Nuclear Power Reactors in the World, Reference Data Series No. 2 (Vienna: International Atomic Energy Agency, April 1995); Leonard S. Spector, Mark G. McDonough, and Evan S. Medeiros, Tracking Nuclear Proliferation: A guide in Maps and Charts, 1995 (Washington: Carnegie Endowment for International Peace, 1995); Robert S. Norris, Andrew S. Burrows, and Richard W. Fieldhouse, Nuclear Weapons Databook: Volume V: British, French, and Chinese Nuclear Weapons (Boulder: Westview Press, 1994); and U.S. Congress, Office of Technology Assessment, Technologies Underlying Weapons of Mass Destruction, OTA-BP-ISC-115 (Washington: U.S. Government Printing Office, December 1993).

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